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REMEDIAL PLANNING ACTIVITIES AT SELECTED UNCONTROLLED HAZARDOUS SUBSTANCES DISPOSAL SITES IN A ZONE FOR EPA REGIONS VI, VII, & VIII

Bonne Terre Mine
MO0985818236
1.5

U. S. EPA CONTRACT NO. 68-W9-0021

5-18-93

FINAL PRELIMINARY ASSESSMENT REPORT FOR SITE ASSESSMENT ACTIVITY OF BONNE TERRE MINE TAILINGS BONNE TERRE, MISSOURI

Work Assignment No.: 013-79ZZ
Document Control No.: 7760-013-F7-RT-CRQD

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U. S. Environmental Protection Agency

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1.0 INTRODUCTION

CDM Federal Programs Corporation (CDM Federal) has been tasked by the United States Environmental Protection Agency (EPA) to conduct Preliminary Assessment (PA) activities for the Bonne Terre Mine Tailings site (CERCLIS ID No.: MOD985818236) under the ARCS Work Assignment No. 013-79ZZ. The Bonne Terre Mine Tailings is a Superfund Accelerated Clean-up Model (SACM) candidate site. Activities for the PA include a file review, background information search, and a site reconnaissance visit to the Bonne Terre Mine Tailings site, Bonne Terre, Missouri, located in St. Francois County. The site reconnaissance was performed by CDM Federal personnel during December 14-16, 1992.

1.1 PRELIMINARY ASSESSMENT OBJECTIVE

The primary objective of the PA was to collect information in support of decisions regarding the necessity of further investigation activities by EPA at the Bonne Terre Mine Tailings site. Analytical data confirms elevated levels of lead, cadmium and zinc in the chat and tailings deposits. Effects on groundwater, surface water, soil and air quality attributed to potential sources of release must be investigated in order to determine immediate or potential threats to human health and the environment.

1.2 SCOPE OF WORK

The scope of this PA investigation includes the following activities:

- Obtain site specific background information and determine CERCLA eligibility. Collect information on potential sources from available EPA files and St. Joe Minerals Corporation.
- Prepare a Management Work Plan (MWP) for activities at this site to include reports and other deliverables to be generated, quality assurance procedures, a level of effort (LOE) schedule along with activity schedule with completion dates.
- Perform onsite reconnaissance: identify private water wells and potential contamination sources; identify public water supply sources; collect information concerning the history of potential sources; and provide photo documentation.
- Compile collected information and calculate a site PA Score.
- Prepare a PA report including a summary of collected information on the Bonne Terre Mine Tailings site and a detailed site map locating potential primary and secondary targets, sources, and exposure pathways.

2.0 SITE DESCRIPTION

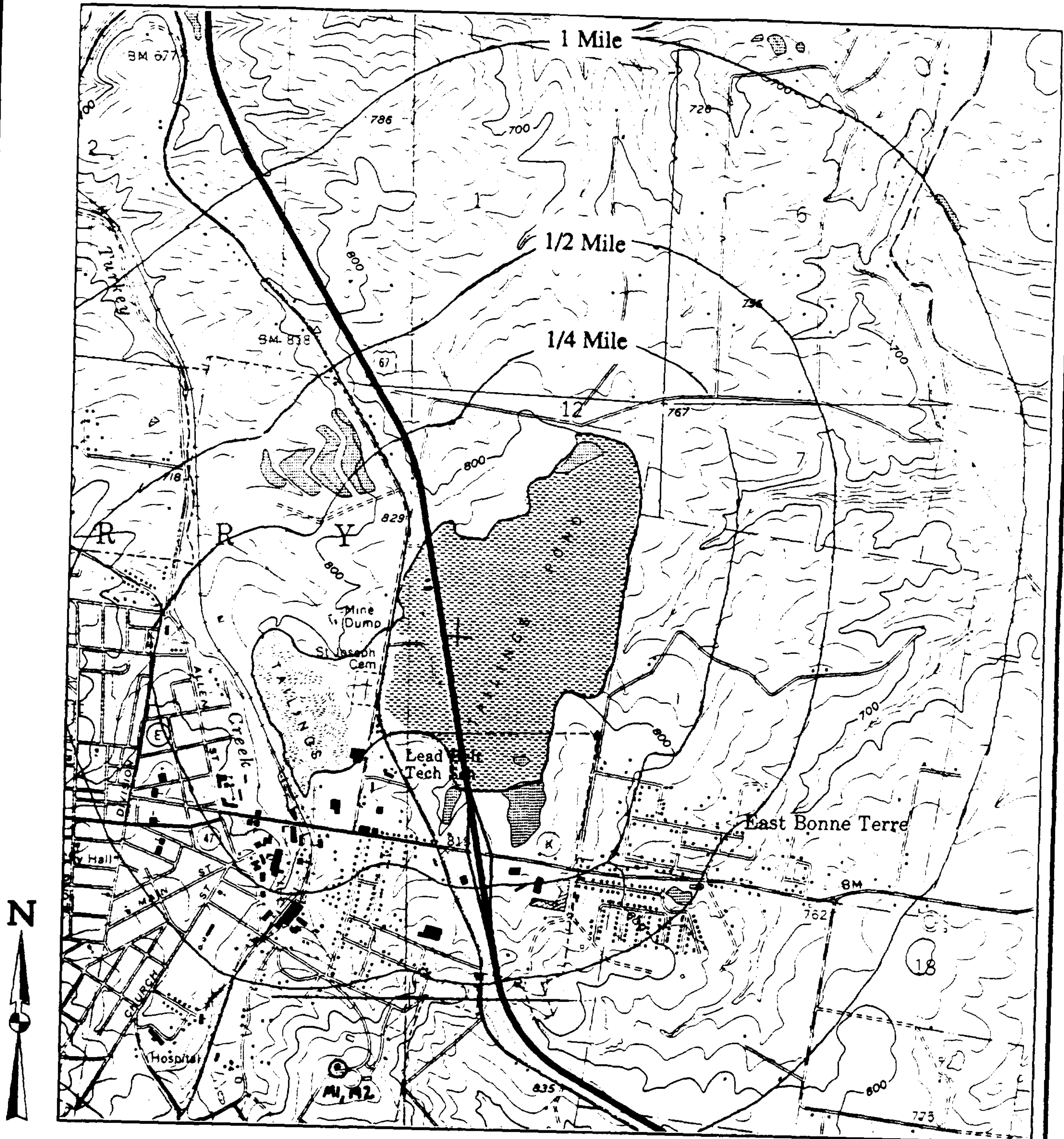
2.1 SITE LOCATION

Bonne Terre is located in the northeastern portion of St. Francois County in Missouri. The small former mining community is located on the Bonne Terre USGS 7.5' topographic quadrangle map (1982) in the east 1/2 of Section 12, Township 37 North, Range 4 East (Figure 2-1). Township/range assessment for the Bonne Terre vicinity is difficult due to the French Long-Lot survey system common in the area. Geographic coordinates for Bonne Terre are 37° 55' 50" N latitude and 90° 32' 22" W longitude (USGS 1982). To reach the site (Figure 2-2), travel south from St. Louis, Missouri, approximately 57 miles on U.S. Highway 67 to the Missouri Highway 47 junction. At the intersection of Highways 47 and 67 in Bonne Terre, the mine tailings field can be seen to the east and the chat pile can be seen to the west. The two mine waste deposits, chat pile and the tailings field, are less than 1/4 mile from one another (CDM Federal 1992).

St. Francois County is characterized by a humid moist continental climate, moderately cool winters, cool springs with fairly heavy rainfall distributed throughout the year, with hot summer months. Winter months are generally below freezing with an average daily minimum temperature of 24° F. Summers are warm to hot with average annual temperatures of 75° F. The record extreme high, 108° F, and low, -20° F were recorded in 1954 and 1964, respectively. Annual total precipitation in St. Francois County averages 23.0 inches. Seasonal snow fall for the area averages 12 inches (USDA/SCS 1981).

2.2 AREA FEATURES /DESCRIPTION

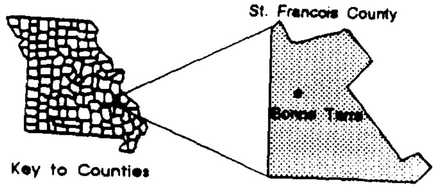
The City of Bonne Terre, Missouri, is located in the northeastern portion of St. Francois county which is physiographically in the eastern edge of the Ozark Highland. Topography in the area ranges from 2 to 53 percent in slope with a dominate agricultural land use (USDA/SCS 1981). Bonne Terre historically was a key mining operation in the Old Lead Belt of Missouri, however has since developed commercial tourism associated with former mining locations (Bonne Terre Mine 1990). Bonne Terre Mine is leased by West End Diving, St. Louis, Missouri, from St. Joe



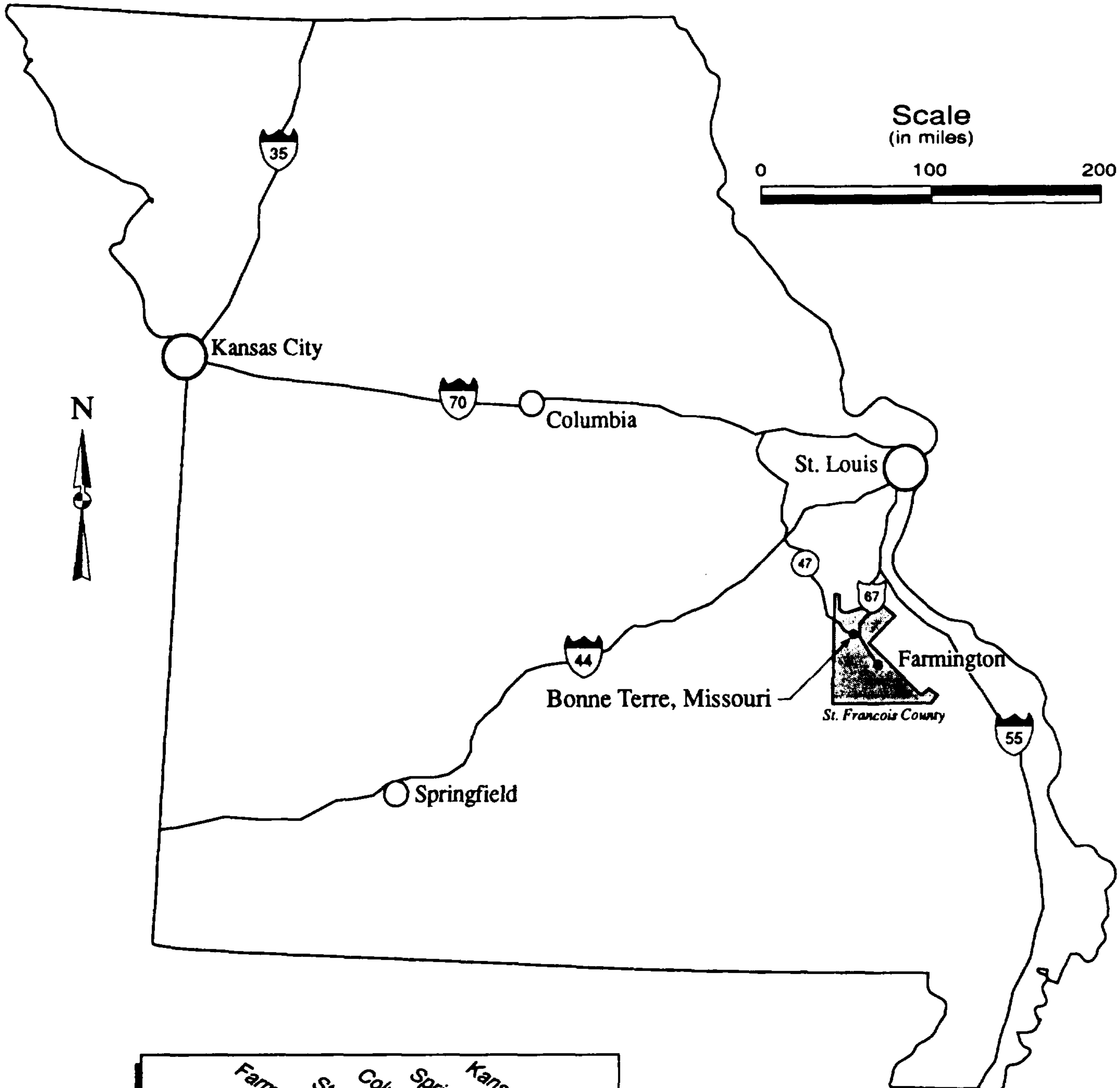
Scale
(in miles)

0 1.0

Source: Bonne Terre USGS Quadrangle 1982



Project No.: 7760-013	Bonne Terre Mine Bonne Terre, Missouri CDM FEDERAL PROGRAMS CORPORATION a subsidiary of Camp Dresser & McKee Inc.	Site Location Map	Figure No.: 2-1 1/93



	Farmington, MO	St. Louis, MO	Columbia, MO	Springfield, MO	Kansas City, MO
Bonne Terre, MO	*11*	*57*	*152*	*218*	*282*

Highway Mileage Table

Source: Rand McNally, Missouri 1975

Project No.: 7760-013	Bonne Terre Mine Tailings Bonne Terre, Missouri CDM FEDERAL PROGRAMS CORPORATION a subsidiary of Camp Dresser & McKee Inc.	Site Route Map	Figure No.: 2-2 1/93

Minerals Corporation, Irvine, California, and conducts approximately 85,000 walking and boating tours annually. The flooded lower levels of the mine offer a unique opportunity for scuba divers. Approximately 15,000 dives take place in the mine annually. Walking tours have been conducted since 1968, scuba diving since 1980, and boating tours recently began in 1990 (Loewe 1993). Bonne Terre, Missouri, is reported as having a 1990 population 3,819 persons.

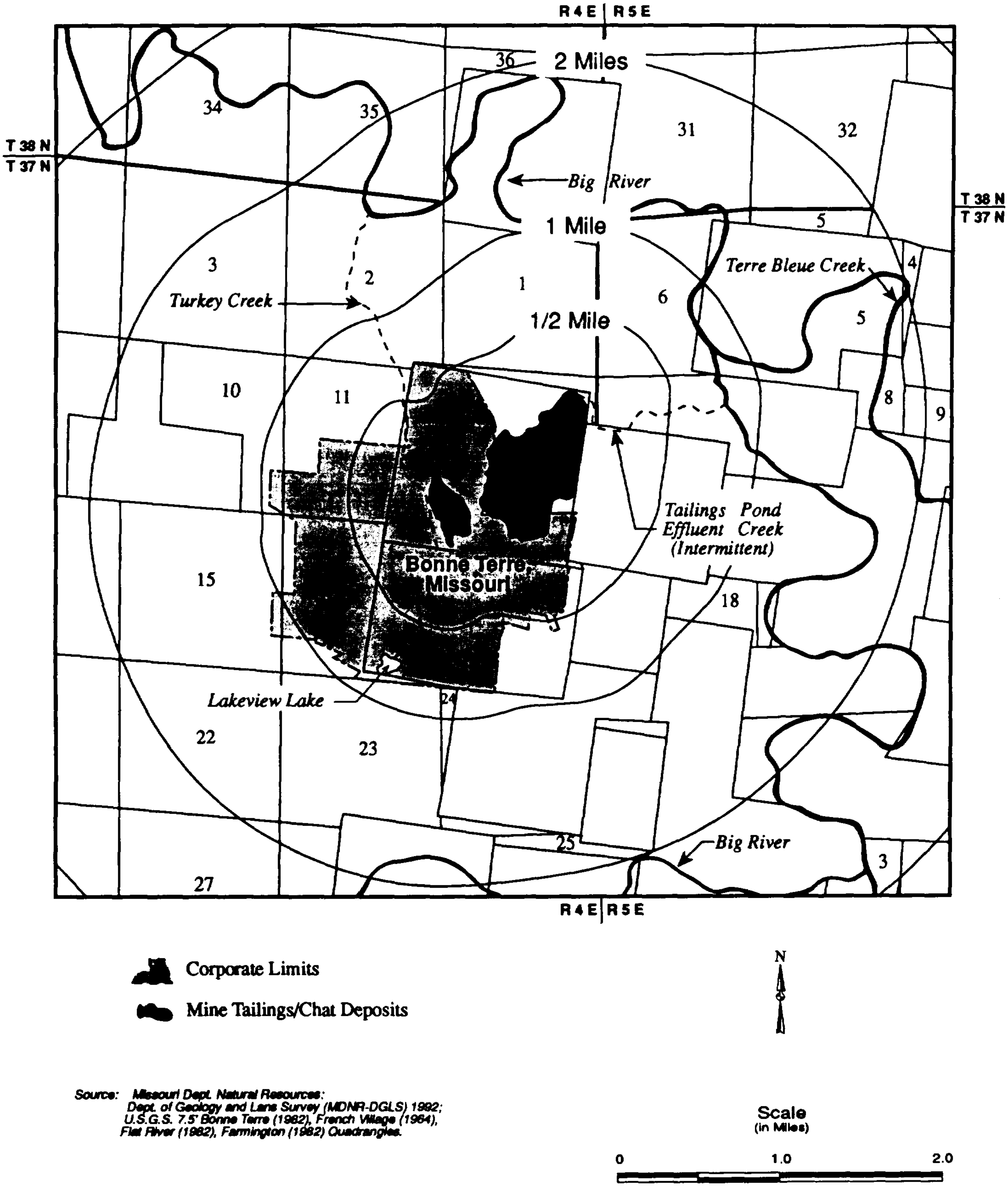
Primarily the ground cover in the area consists of grass vegetation with sparse to heavily wooded areas, and regional agricultural lands. There is no visible evidence of stressed vegetation in the area however, reconnaissance activities were conducted during the dormant winter month of December (CDM Federal 1992).

Surface water runoff for the City of Bonne Terre is controlled by storm sewers that flow into Turkey Creek (Figure 2-3) which flows north approximately 10,600 feet to the Big River. (CDM Federal 1992, Loewe 1993). There are no drinking water intakes for surface water located on Turkey Creek or Big River within the Bonne Terre area of concern. According to the Mineral and Water Resources of Missouri (1967), Big River is utilized for recreation, fish propagation and for the dilution and transportation of municipal and industrial wastes. Turkey Creek is suspected to be a local fishery near the confluence with Big River (CDM Federal 1992).

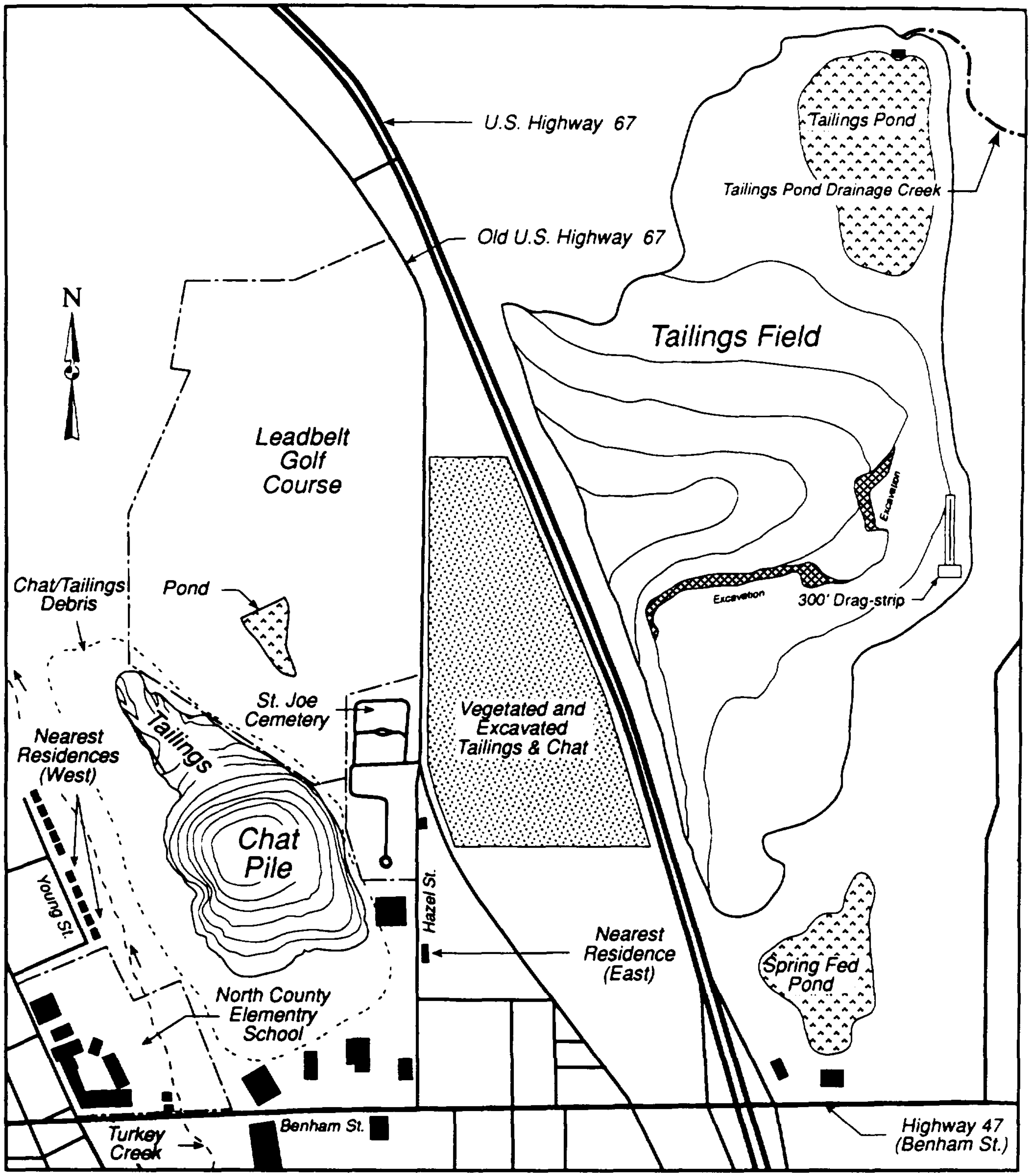
2.3 SITE FEATURES /DESCRIPTION

The Bonne Terre Mine Tailings site is primarily divided into two areas (Figure 2-4), a chat pile and the tailings field. The most noticeable feature of the site is the unusually large chat pile located north of Benham Street and west of Hazel Street in Bonne Terre, Missouri.

Chat Pile: For the purpose of this report, chat will be defined as coarse gravel crushed to 3/8" or less in size. The pile was reported to have covered approximately 50 acres and was approximately 160 feet in height at its maximum (Wixson 1983). Currently the pile covers approximately 32 acres and is estimated to be 100 to 120 feet high (St. Francois County 1982, CDM Federal 1992). Throughout the years portions of the chat pile have been excavated and hauled away (CDM Federal 1992). It is unknown as to where excavated portions of the pile were transported. St. Joe



Project No.: 7760-013	Bonne Terre Mine Tailings Bonne Terre, Missouri CDM FEDERAL PROGRAMS CORPORATION a subsidiary of Camp Dresser & McKee Inc.	Surface Water Map	Figure No.: 2-3 1/93



Source: University of Missouri—Rolla 1983; CDM Federal 1992; St. Francois County 1982; Farmington Chamber of Commerce 1992.

Project No.: 7760-013	Bonne Terre Mine Tailings Bonne Terre, Missouri CDM FEDERAL PROGRAMS CORPORATION a subsidiary of Camp Dresser & McKee Inc.	Site Map	Figure No.: 2-4 1/93

Minerals Corporation, Irvine, California, currently owns the chat pile property. Northwest of the chat pile, a tailings/erosional field is present covering approximately 14 acres. Ms. Sybil Counts of Bonne Terre currently owns the tailings/erosional field. The tailings sediment is estimated to be 30 feet thick (CDM Federal 1992).

The site is bordered by residential and commercial areas on the east, west and south sides. Leadbelt Golf Course lies to the north of the chat pile. St. Joseph Cemetery is adjacent to the chat pile to the east. North County Elementary school is adjacent to the chat pile to the west. Small commercial businesses are located south of the chat pile. Residential areas are located along Hazel street, east of the chat pile and Young street west of the pile (CDM Federal 1992).

Ground cover in the area of the chat pile is sparse, mostly gravel (chat) and fine clay-like sediments (possible eroded tailings). Stressed vegetation in and around the chat pile was possible, however, reconnaissance activities were conducted during the dormant winter month of December (CDM Federal 1992).

Surface drainage from the chat pile follows natural erosion routes approximately 200 feet towards the west to northwest flowing into Turkey Creek. The chat pile is unrestricted to public access, however is fenced on the east side (CDM Federal 1992).

Tailings: The tailings field is located approximately 1/4 mile east of the chat pile. For the purpose of this report, tailings will be in reference to medium to fine sand sized particles. The tailings field covers approximately 160 acres (St. Francois County 1982). Thickness varies from ground surface in the southern portion to approximately 50 feet thick in the north end (Black 1993).

Approximately five acres in the southern portion of the field have been seeded with grass. According to Damon Black (1992), owner of the tailings field, the grass needs to be fertilized annually in order for the grass to thrive. Approximately 3 percent of the tailings field is vegetated. The remaining ground cover for the tailings field remains barren (CDM Federal 1992). Excavation of the tailings has occurred over the past 75 years in the central portion of the field.

In the central portion of the tailings field, tailings were excavated and hauled away to be used for construction footings, fill material, and agricultural lime throughout the Bonne Terre area (Black 1993). On the east side of the field, Big River Sand Drags, Bonne Terre, Missouri, leases a portion of the field from Damon Black for drag-racing purposes. Drag-racing at this site occurs during the months of April through September on a constructed 300 foot drag-strip. Drag-racing has occurred at this site since 1990 according to Damon Black (CDM Federal 1992).

A tailings pond is located at the north end of the tailings field. The pond is approximately five acres in surface area and ranges between two and four feet deep (Black 1992). Surface drainage for the tailings field flows from south to north. The tailings field is contained on the north and east side by an impoundment dam constructed of pore rock and clay (Black 1992).

Surface water drainage release for the tailings pond is controlled by a decanting tower located at the north end of the tailings pond. Excess surface water is routed through the decanting tower to an intermittently flowing creek that flows easterly approximately 5,700 feet to the Big River (CDM Federal 1992, St. Francois County 1982).

Intermediate Tailings/Chat: Between the chat pile and the tailings field there are patchy deposits of tailings and chat. Approximately 53 acres between Old U.S. Highway 67 and U.S. Highway 67 is covered with chat/tailings debris. Ms. Mary Berry of Bonne Terre, Missouri, currently owns a 25 acres section of the intermediate tailings and chat. The small chat pile located on the Berry property was being excavated and hauled away according to Damon Black (1992). No information as to what company and where the mine deposits were being transported to was available.

3.0 OPERATIONAL HISTORY AND WASTE CHARACTERISTICS

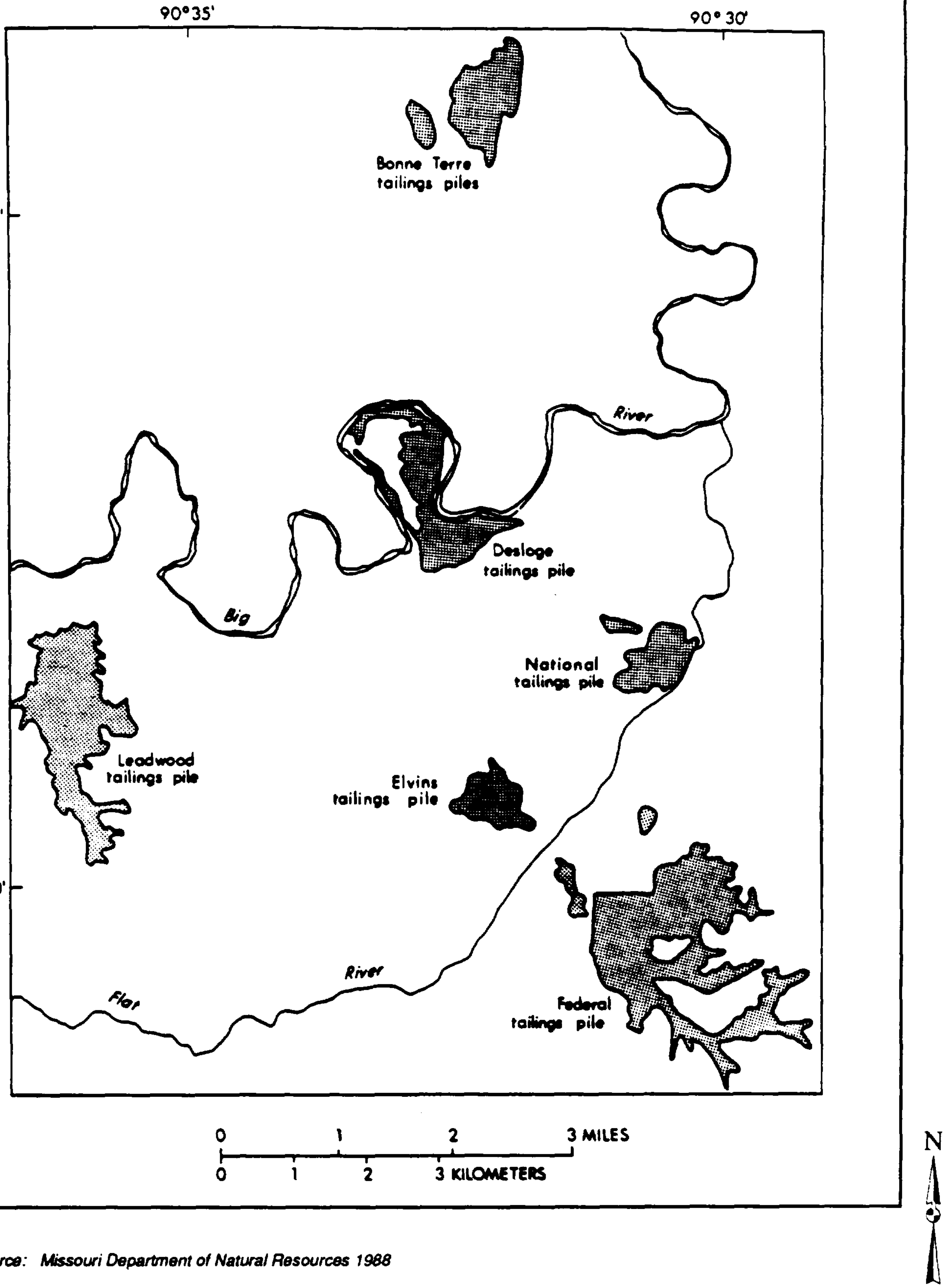
3.1 OPERATIONAL HISTORY

The Old Lead Belt located in the southeastern region of the state of Missouri (Figure 3-1), was the Nation's largest producer of lead through the years 1907 to 1953. During this period approximately eight million tons of lead were produced leaving behind more than 227 million tons of crushed rock in the form of chat, tailings and fine mill slime (Hass 1986, Smith 1988). Bonne Terre Mine was credited with producing over 30 million tons of lead ore valued at $125 million dollars (Blackwell 1982). Mining activities date back to the 1700's at the Bonne Terre site.

France had heard rumors of mineral wealth in the St. Francois County area around 1700. LeSuer was dispatched from France to assay the mineral resources of southeastern Missouri in hopes to discover silver in conjunction with lead deposits. Based on LeSuer's discoveries, France sent Renault with his slaves into the territory. This was the beginning of the mining industry in the Bonne Terre area. During the Spanish land grant in 1800, the Pratte brothers purchased land that would later become the Bonne Terre town site. The land was later purchased from the Pratte brothers by LaGrave. A prospector from Iron Mountain purchased LaGrave's Bonne Terre interest for $80,000 during the onset of the Civil War. In 1864, the St. Joseph Lead Company was formed by a group of New York investors who purchased 964 acres in the Old Lead Belt including the Bonne Terre Mine site (Smith 1988, Blackwell 1982, Wixson 1982).

Mining methods in the early days were crude and restrictive. Lead sheets 4 to 8 feet thick were exposed and blasted into pieces that could be handled, then broken again by hammers, then transported to a pulverizer. The ore was then "jigged" up and down in water to separate coarse lead from stone overburden and wash away dirt. The ore was then melted in reverberatory furnaces and hand ladled into iron molds. Hence this early method of density separation was referred to as jigging (Blackwell 1982).

In 1869 the first diamond drill was brought to Bonne Terre by Albert Shepard. With the introduction of the diamond drill, shafts were sunk and drifts (horizontal tunnels) and headings (or



Source: Missouri Department of Natural Resources 1988

Project No.:	Bonne Terre Mine Tailings Bonne Terre, Missouri	Old Lead Belt	Figure No.:
7760-013	CDM FEDERAL PROGRAMS CORPORATION a subsidiary of Camp Dresser & McKee Inc.		3-1
			1/93

work space) could be blasted (Smith 1988). Mine production continued to grow in the Bonne Terre area and production increased with each new technology (Blackwell 1982).

A new lead extraction process, froth flotation, was introduced in 1915. This process is still currently being utilized for lead extraction in the new lead belt or Viburnum Trend located further west from the Old Lead Belt (Thompson 1992, Blackwell 1982).

The froth flotation required mine workings to be further crushed into a fine sand to powder-like consistency. Once crushed the ore was extracted by being mixed into a slurry and then introduced to chemicals that act as lifting agents for the lead deposits in a bath. The principal chemical utilized in this process is sodium cyanide. The lead interaction with the sodium cyanide caused the lead to be entrapped in the froth air bubbles and be carried to the top of the mixing bath. At this point lead laden froth was then skimmed off the bath surface. The milling waste produced from this process was referred to as "slime" (tailings) due to its pasty consistency. To produce one ton of lead, 6 1/2 tons of water was required for this process. (CDM Federal 1992, Blackwell 1982, Thompson 1992) Slime (or tailings) waste was flushed down creeks which fed Big River. Farmers in the 1920s filed lawsuits against St. Joe Lead Company claiming the flushed mine waste (slime) had ruined their crop land. There are no successful settlements recorded (Blackwell 1982).

In 1916, St. Joe Lead Company erected a chat conveyor which was used to stockpile the huge mountain-like chat pile. Previously mine wastes had to be hauled away by railroad and dumped wherever feasible (Blackwell 1982).

Mined ore from the Bonne Terre averaged 5 to 6 percent lead with concentrations of sulfur (13%), nickel (<1%), and silver (0.08%). During the last years of the operation of the Bonne Terre Mine, lead ore concentrations were below 2 percent. The most employees recorded at Bonne Terre in 1907 with 800 personnel (Fairclothe 1993). During the later years, Bonne Terre mine was producing 1800 tons of lead ore per day with 200 employees (Blackwell 1982, Fairclothe 1993). The richer deposits being developed in the Viburnum trend ultimately forced the closure of the Bonne Terre Mine in 1961. An estimated 267,400,000 cubic feet of material was removed from the Bonne Terre mine in its 98 year history (Loewe 1993).

The Bonne Terre Mine Tailings site is now abandoned. Caretaking activities of the site are conducted for St. Joe Minerals Corporation by Hudwalker & Associates, Inc., a consulting engineering firm:

Hudwalker & Associates, Inc.
505 Potosi Street
P. O. Box 676
Farmington, Missouri 63640
314-756-6775

3.2 WASTE CHARACTERISTICS

There are two potential sources at the Bonne Terre Mine site, chat and tailings. Chat will be defined as ore material crushed (milled) to ⅜" or less. Chat was primarily milled with the density separation (jigged) process. Tailings will be defined as milled material of medium to fine sand size or smaller. Tailings were primarily produced from the froth floatation-level extraction process. Each mine waste is being considered a potential source based on the different lead extraction techniques associated with each deposit. The hazardous contaminates are however the same with each source. The principal hazardous waste concerns at the Bonne Terre Mine Tailings site are heavy metals, specifically lead, cadmium and zinc as defined by similar and previous tailings contamination studies by Wixson (1982, 1983), Haas (1986), and Trial (1985). Potential pathway exposure to surface water, groundwater, nearby soils and the air are highly likely and will be discussed in section 5.0 of this report. This section will discuss the three heavy metals, lead, cadmium, and zinc, their characteristics, and potential hazards.

Lead (Pb)

Lead exists in nature primarily as galena (lead sulfide—PbS). Other forms of lead are cercissite (lead carbonate—$PbCO_3$), anglesite (lead sulfate—$PbSO_4$), and pyromorphite (lead chlorophosphates—$Pb_5(PO_4)_3Cl$) (Bates 1987). Lead is a toxic metal that when released into the environment tends to have a long residence time compared to most other pollutants. As a result, lead and its compounds, tend to accumulate in soils and the tissues of humans and other animals. The low solubility and relative freedom from microbial degradation, give a high eco-toxicity characteristic to lead (Alloway 1990). The major toxic effects of lead exposure include acute ataxia, repeated vomiting, headache, stupor, tremors, convulsions, and coma. The Occupational Safety and Health Administration (OSHA) Threshold Limit Value (TLV) for leaded dust exposure is 0.05 mg/m^3. The EPA Superfund Chemical Data Matrix (1992) lists lead with a toxicity value of 10,000 for the groundwater pathway. The Federal Maximum Contaminant Limit (MCL) for lead concentrations in drinking water is 0.05 mg/L, however, a more stringent action level of 15 μg/L is recommended by the World Health Organization (WHO) (EPA 1992). There are no warning concentrations listed for lead contaminated soil (Patnaik 1992).

Cadmium (Cd)

Cadmium is a relatively rare metal and highly toxic to plants and animals. Mining, smelting and ore-dressing of cadmium containing sulphide ores can contain up to 5% cadmium. The major chronic hazard for cadmium exposure is accumulation in the kidneys which could ultimately result in failure (Alloway 1990). Acute toxic symptoms include: nausea, vomiting, diarrhea, headache, abdominal pain, and shock (Patnaik 1992). OSHA recommends a threshold limit value of 0.1 mg $/m^3$ for dusts and salts. Cadmium has a toxicity value of 10,000 for the groundwater pathway (EPA 1992). The MCL for drinking water listed for cadmium is 0.01 mg/L (EPA 1992). Cadmium has an EPA (1992) listed reference dose of 290 mg/Kg for soil.

Zinc (Zn)

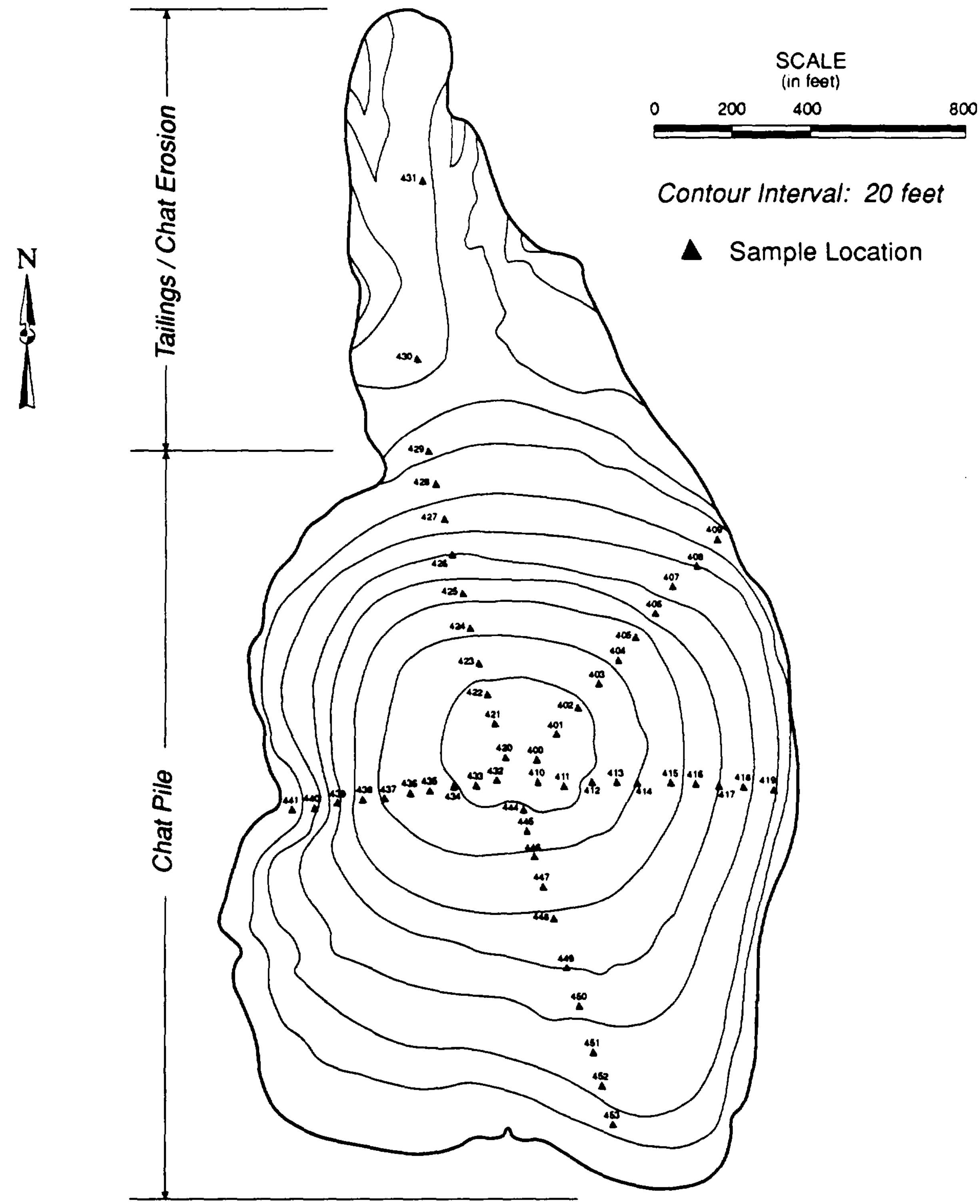
Zinc is commonly found as a sulfide, and in association with other metals, specifically lead, cadmium, iron and copper. Zinc is an essential trace element for humans, plants and animals. A safe dietary intake of zinc is around 15 mg/day for adults (Alloway 1990). Toxic effects from zinc inhalation can cause weakness, dryness of the mouth, chills, and nausea. Airborne warning concentrations are not established for zinc dust (EPA 1992, Patnaik 1992). There is no established MCL for zinc in drinking water. Zinc has a relatively low toxicity value of 10 for the groundwater pathway. A reference dose for soil is listed as 120,000 mg/kg.

3.3 PREVIOUS STUDIES

The University of Missouri - Rolla conducted soil sampling activities at the Bonne Terre Mine Tailings site in 1983. Samples collected included 52 chat pile (Figure 3-2) and 36 tailings field (Figure 3-3) samples. Samples were analyzed for lead, cadmium and zinc content. No background samples were collected for this activity. Raw analytical results indicate elevated levels of all three metal contaminates, however, no background comparisons were performed to concentrations common in the Bonne Terre area. Lead concentrations ranged from 1,300 ppm to 7,010 ppm with a mean concentration value of 3,515 ppm. Cadmium was detected ranging from 3.0 ppm to 29.5 ppm with a mean concentration of 13.9 ppm. Zinc was identified in concentrations ranging from 51.3 ppm to as high as 967.0 ppm and a mean concentration of 541.0 ppm. Based on this sampling event, an observed release has been identified in the mine deposits. The extent of the release cannot be established from the available information. Tables 3-1 and 3-2 summarizes the analytical results for this sampling activity. The available analytical data for this sampling activity has been included as Appendix D.

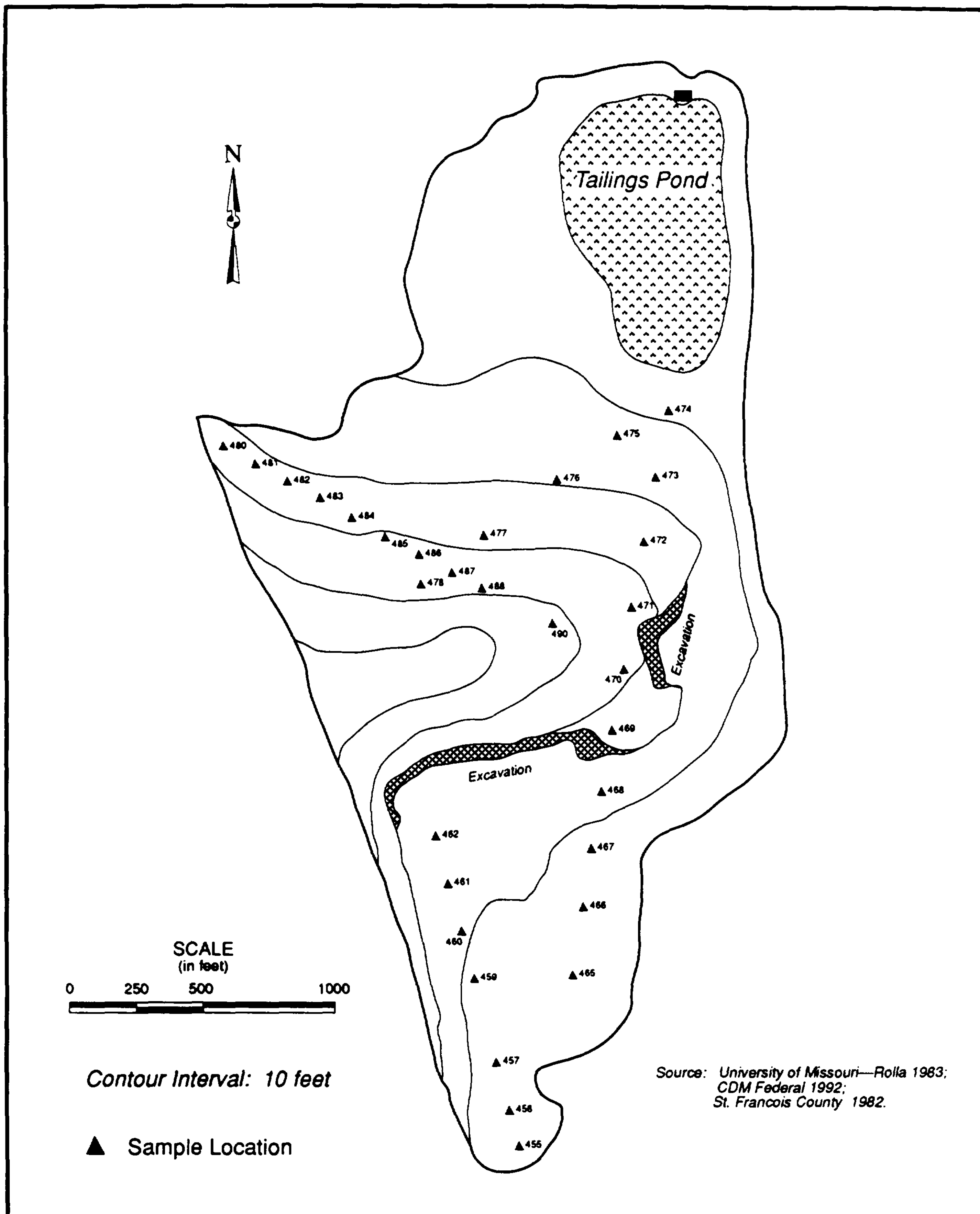
A number of studies have been conducted in the Bonne Terre area concerning lead accumulation in fish tissue. Work conducted by Hass, Gale and Wixson (1986) through the University of Missouri - Rolla, have identified lead accumulation in a number of bottom feeding fish in the Big River. Filets of suckers and some species of sunfish collected from the Big River and its tributaries have been found to contain concentrations of lead in excess of 0.3 $\mu g/g$, the recommended limit for lead in food according to the World Health Organization (WHO). Excerpts of this study and the analytical summary are included in Appendix D.

Similar studies conducted at the Leadwood, Desloge-Big River, National, and Elvins mine tailings sites have concluded that tailings and surface water runoff from the tailings have affected the sediments of the Big River and other local streams. Elevated patterns of lead levels suggest that the problem exists throughout the Leadwood, Desloge, Flat River, and Bonne Terre region (Wixson 1982).



Source: University of Missouri—Rolla 1983;
CDM Federal 1992;
St. Francois County 1982.

Project No.: 7760-013	Bonne Terre Mine Tailings Bonne Terre, Missouri CDM FEDERAL PROGRAMS CORPORATION a subsidiary of Camp Dresser & McKee Inc.	University of Missouri—Rolla Soil Sample Locations Bonne Terre Chat Pile	Figure No.: 3-2 1/93



Project No.:	Bonne Terre Mine Tailings Bonne Terre, Missouri	University of Missouri—Rolla Soil Sample Locations Bonne Terre Tailings Field	Figure No.:
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Table 3-1
University of Missouri — Rolla
Soil Analytical Summary
Bonne Terre Chat Pile

Sample Number	Metal Concentration (ppm)		
	Lead	Cadium	Zinc
400	5330	9.7	469
401	5020	5.4	273
402	1300	10.2	309
403	2020	9.9	430
404	2280	11.7	451
405	3540	11.9	689
406	3070	12.1	718
407	1890	17.6	650
408	1540	12.3	587
409	3230	14.9	501
410	3590	13.9	51
411	4120	13.4	671
412	4450	17.7	757
413	3140	14.4	722
414	4350	12.0	309
415	2540	16.1	757
416	3040	16.4	648
417	1630	9.6	486
418	1840	13.7	597
419	1760	10.0	641
420	1480	3.0	150
421	3080	5.5	194
422	2050	13.3	434
423	1940	13.0	479
424	2190	13.5	458
425	2380	15.1	573
426	2390	17.2	622
427	1580	15.1	553
428	1860	14.2	686
429	1340	13.9	661
430	4720	29.5	786
431	2650	7.0	150
432	3200	15.2	705
433	3200	15.8	650
434	7010	8.2	426
435	6670	15.3	477
436	5820	10.9	361
437	5210	18.1	559
438	4290	11.5	573
439	6730	13.6	755
440	6840	12.8	618
441	5800	16.0	180
444	3280	15.1	511
445	4530	13.6	444
446	4220	17.4	697
447	5030	19.2	746
448	5980	22.5	967
449	5190	28.8	623
450	3390	22.4	922
451	3540	22.0	878
452	2791	15.7	563
453	6230	10.4	539

Note: Sample Nos. 442 and 443 are excluded from the sampling sequence.

Table 3-2
University of Missouri — Rolla
Soil Analytical Summary
Bonne Terre Tailings Field

Sample Number	Metal Concentration (ppm)		
	Lead	Cadium	Zinc
455	1232	5.9	173
456	3020	10.2	361
457	6650	10.5	312
458	1810	5.9	385
459	1600	9.0	354
460	1920	12.3	491
461	1170	9.3	312
462	1610	10.0	234
463	989	8.4	185
464	1560	7.3	205
465	1550	11.2	244
466	2310	12.0	380
467	1540	10.8	366
468	3450	10.4	243
469	1620	9.5	255
470	1860	6.0	157
471	1520	4.5	87
472	2710	6.3	222
473	1170	3.6	99
474	660	7.9	151
475	1440	4.7	156
476	2610	4.9	330
477	1320	6.0	165
478	1900	13.2	337
479	1760	9.8	273
480	1290	13.8	524
481	1480	15.1	543
482	1780	13.3	321
483	1820	5.6	618
484	1400	6.7	171
485	2840	10.0	1470
486	7610	20.9	698
487	1590	6.7	152
488	1020	6.4	115
489	1950	8.1	321
490	1120	5.2	170

Environmental studies conclude significant impacts to include: channel flow changes, water temperature variation, increased stream turbidity, invertebrate population reduction, and excessive plant growth have been attributed to water quality below tailings ponds (Trial 1985).

A special drinking water standard inorganic analysis was conducted on the Bonne Terre Municipal Well No. 1 and No. 3 in June, 1991, and December, 1989, respectively. Samples were collected and analyzed for: pH, residue, sulfate, total alkalinity, phenolphtalein, bicarbonate, carbonate, chloride, calcium, magnesium, hardness, arsenic, selenium, lead, cadmium, barium, chromium, silver, iron, manganese, zinc, copper, sodium, potassium, mercury, fluoride, and nitrates. All parameters were found to be within acceptable drinking water standards for the State of Missouri. Lead and cadmium were detected in concentrations less than 0.005 mg/L, zinc in concentrations less than 0.10 mg/L for both sampling events (MDNR 1992).

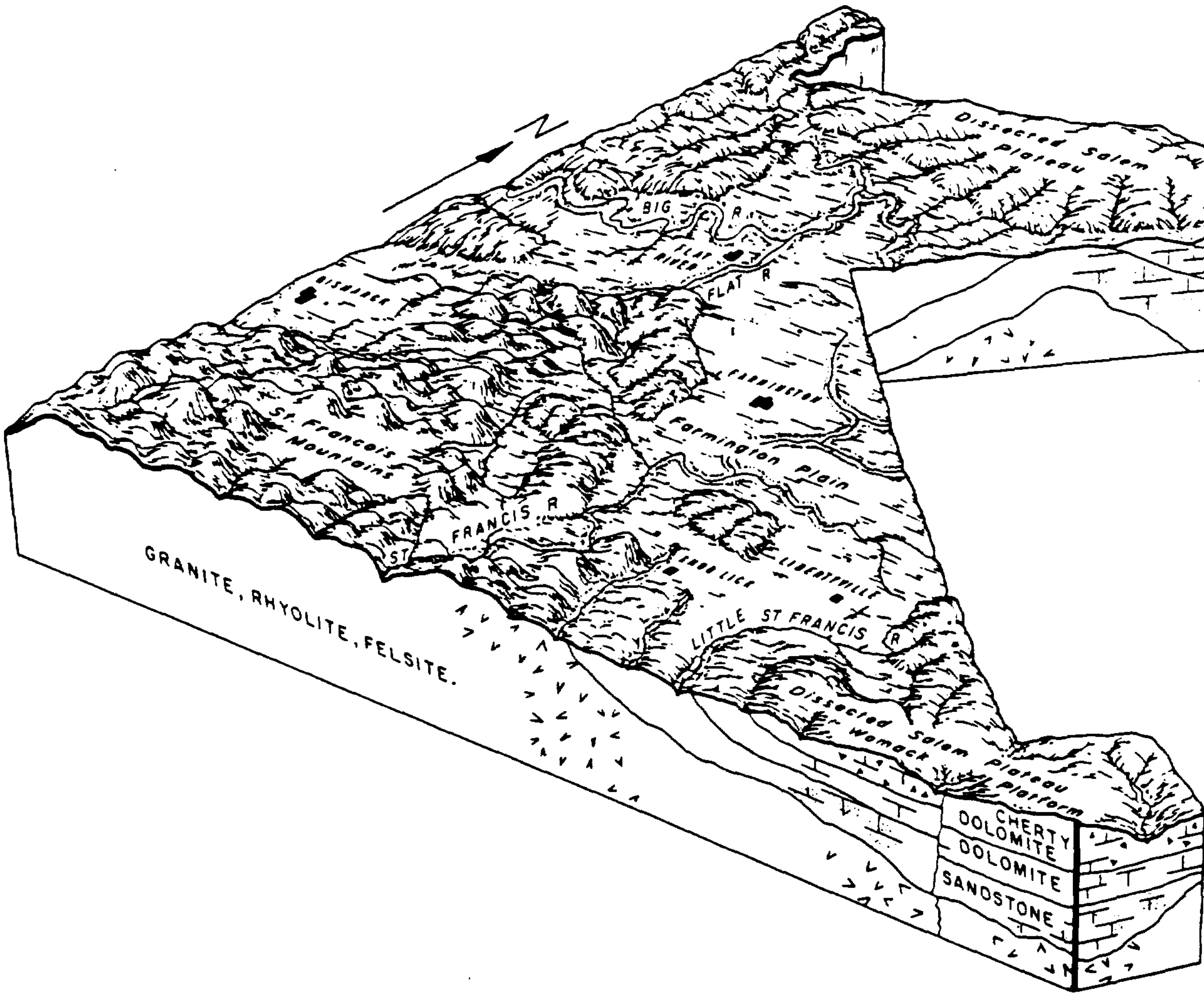
4.0 ENVIRONMENTAL SETTING

4.1 GEOLOGIC SETTING

St. Francois County is located in the Ozark High Plains physiographic region of Missouri. The Farmington Plain (Figure 4-1) would be representative of the geology common in the Bonne Terre area. This region is underlain by the Cambrian aged Derby-Doerun dolomite, Davis shales, Bonneterre dolomite and Lamotte sandstones (USDA/SCS 1981). Soils in the Bonne Terre area are classified as the Caneyville-Crider-Gasconade Association and consist primarily of well-drained loess and clayey material. The soils have low permeability and act as an aquitard shielding the deeper aquifer of the Bonneterre and Lamotte formations (USDA/SCS 1981). Nevertheless, due to karst terrain and the numerous mine shafts, it would be reasonable to believe that surface water infiltration to lower stratum would be highly likely under these conditions. The youngest formation common to the Bonne Terre area is the Derby-Doerun Formation (Figure 4-2). The Derby-Doerun is identified by the thin to medium-bedded dolomite alternating with thinly bedded siltstone and shales. Glauconite is present in the lower 40 to 50 feet of the formation. The average thickness for this unit is 150 feet, however, range from 0 to 200 feet (MGSWR 1967).

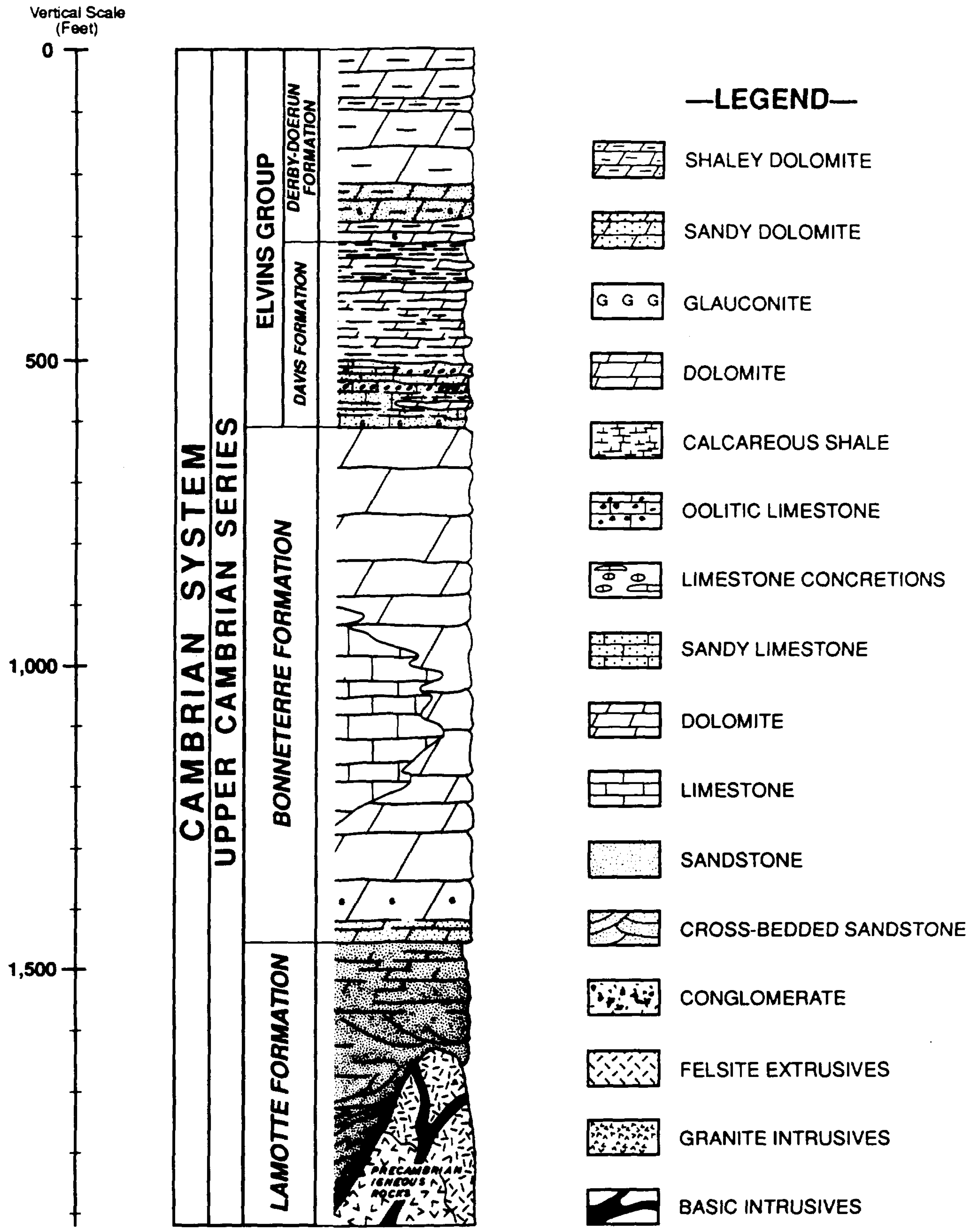
The Davis Formation is the lower of the two formations that comprise the Elvins Group. The formation is conformable with the underlying Bonneterre and contains shale, siltstone, fine-grained sandstone, dolomite, limestone and conglomerate limestone. Average thickness for the Davis is 170 feet. Maximum thicknesses have been recorded up to 225 feet for the Davis Formation (MGSWR 1967).

The Bonneterre Formation consists of dolomite and relatively pure limestones in some areas. Shales occur in the unit, less than 2 inches in thickness. Major lead ore deposits have been found in the lower half of the unit. The association of the Bonneterre and the underlying Lamotte Formation is one of conformity. A sandy zone is encountered in the lower reaches of the unit which overlaps into the Lamotte on the flanks of Precambrian highs. A maximum thickness for this formation has been known to exceed 1,500 feet, however, is approximately 350 to 400 feet thick throughout the lead belt area (MGSWR 1967).



Source: USDA Soil Conservation Service 1981

Project No.: 7760-013	Bonne Terre Mine Tailings Bonne Terre, Missouri CDM FEDERAL PROGRAMS CORPORATION a subsidiary of Camp Dresser & McKee Inc.	Physiography	Figure No.: 4-1 1/93



Source: Stratigraphic Succession in Missouri 1961.

Project No.: 7760-013	Bonne Terre Mine Tailings Bonne Terre, Missouri CDM FEDERAL PROGRAMS CORPORATION a subsidiary of Camp Dresser & McKee Inc.	Regional Geology	Figure No.: 4-2 1/93

The oldest unit common in the Bonne Terre area is the Lamotte sandstones. These quartzose sandstones grade laterally into arkose and conglomerate lithologies. The conglomerate zones are primarily associated with Precambrian intrusions and extrusions. The Lamotte sandstone can attain thicknesses of up to 500 feet. However, the Lamotte Sandstone is generally 200 feet in thickness (Figure 4-3) (MGSWR 1967).

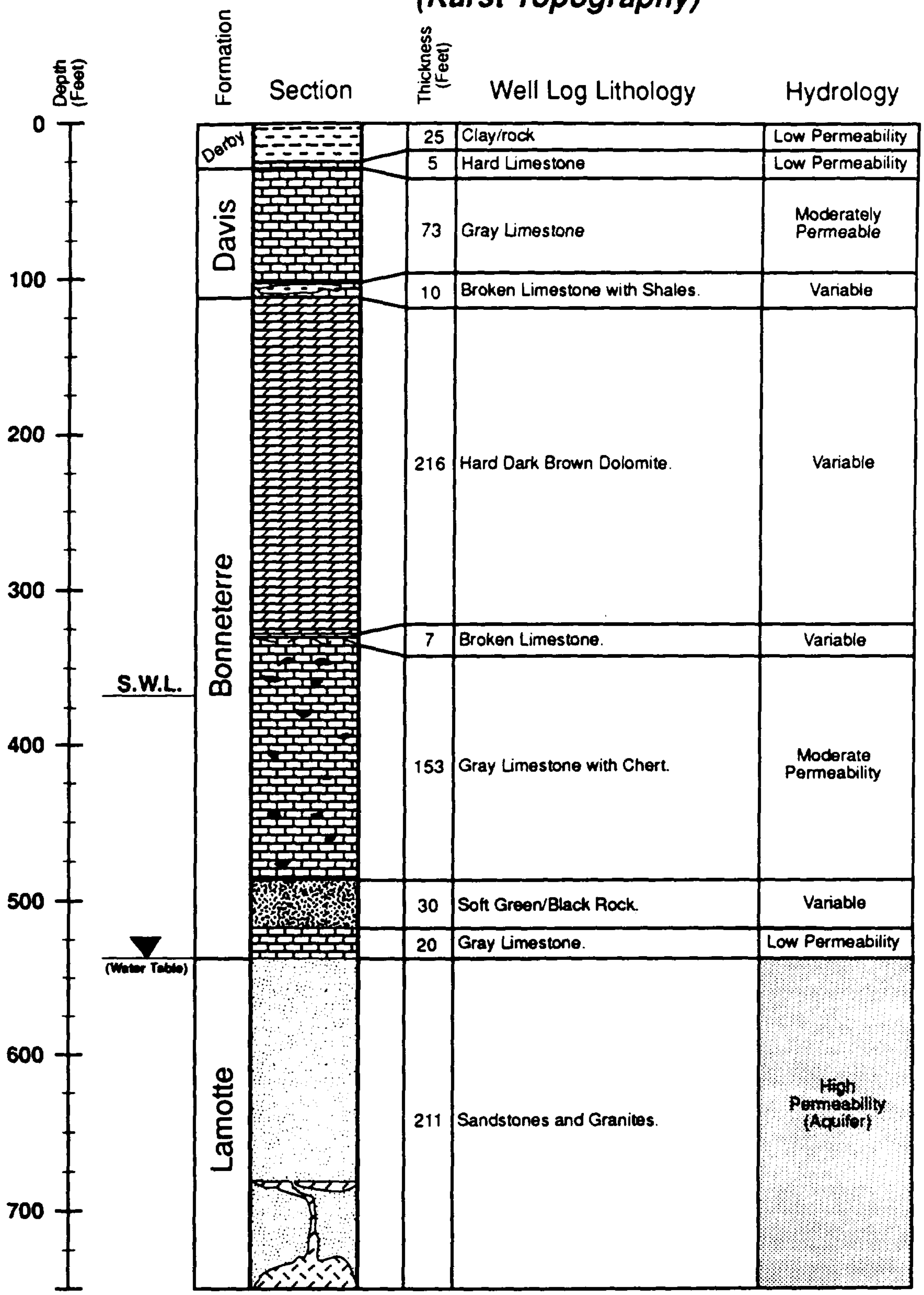
4.2 HYDROLOGIC SETTING

Karst terrain is assumed for the Bonne Terre Mine Tailings site, however, no Karst terrain features were identified in the Bonne Terre area (CDM Federal 1992). The principal water bearing unit is the Lamotte sandstones, however, water bearing units have been identified within the Bonneterre Formation. All potable water is derived from municipal or private drinking water wells. There are no known surface water intakes within the investigation extent. Private well information is limited. Locations of registered wells in the Bonne Terre area are difficult to assess due to the French Long-lot survey system common in the area. Therefore, wells that may potentially lie within the 4-mile radius of the site were omitted due to questionable placement. Within a 2-mile radius of Bonne Terre, Missouri there are 39 registered wells (Figure 4-4, Table 4-1) (MDNR/DGLS 1992). Private wells range in depth from 143 feet to 485 feet. Depth to static water level ranges from 20 feet to 200 feet below the surface. Based on the private well information associated with the Bonne Terre area, an average static water level is 90 feet (MDNR/DGLS 1992).

The city of Bonne Terre, Missouri, is serviced by three blended municipal wells. Wells No. 1 and No. 2 are both drawing water from an abandoned mine shaft located in the southeast portion of the town (Figure 4-5). Both wells are drawing water from 730 feet with a combined output of 615 GPM (Varner 1993). Municipal Well No. 3 is a drilled well finished at 750 feet in Section 13, Township 37 North, Range 4 East (Figure 4-3). Well No. 3 is drawing water from the Lamotte Sandstones at 310 GPM. The static water level was recorded as 360 feet during the well installation on July 24, 1964 (MDNR/DGLS 1992). All three of the Bonne Terre municipal wells are in the ½ to 1 mile radius zone from the site.

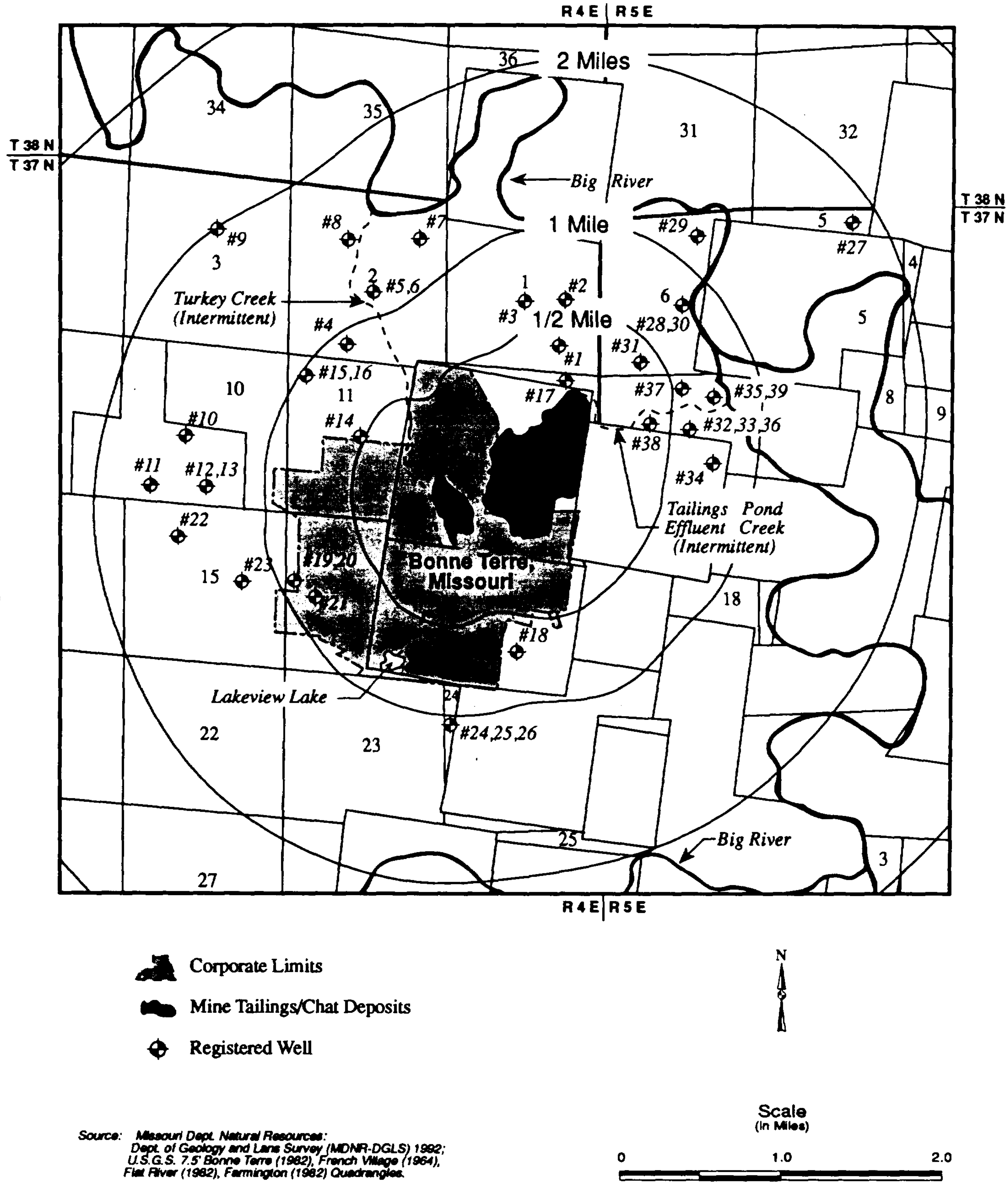
—Bonne Terre Municipal Well No. 3—

(Karst Topography)



Source: Dept. of Revenue, State of Missouri 1988;
MGS and Water Resources 1964.
D. Varner 1993;

Project No.: 7760-013	Bonne Terre Mine Tailings Bonne Terre, Missouri CDM FEDERAL PROGRAMS CORPORATION a subsidiary of Camp Dresser & McKee Inc.	Local Geology	Figure No.: 4-3 12/92

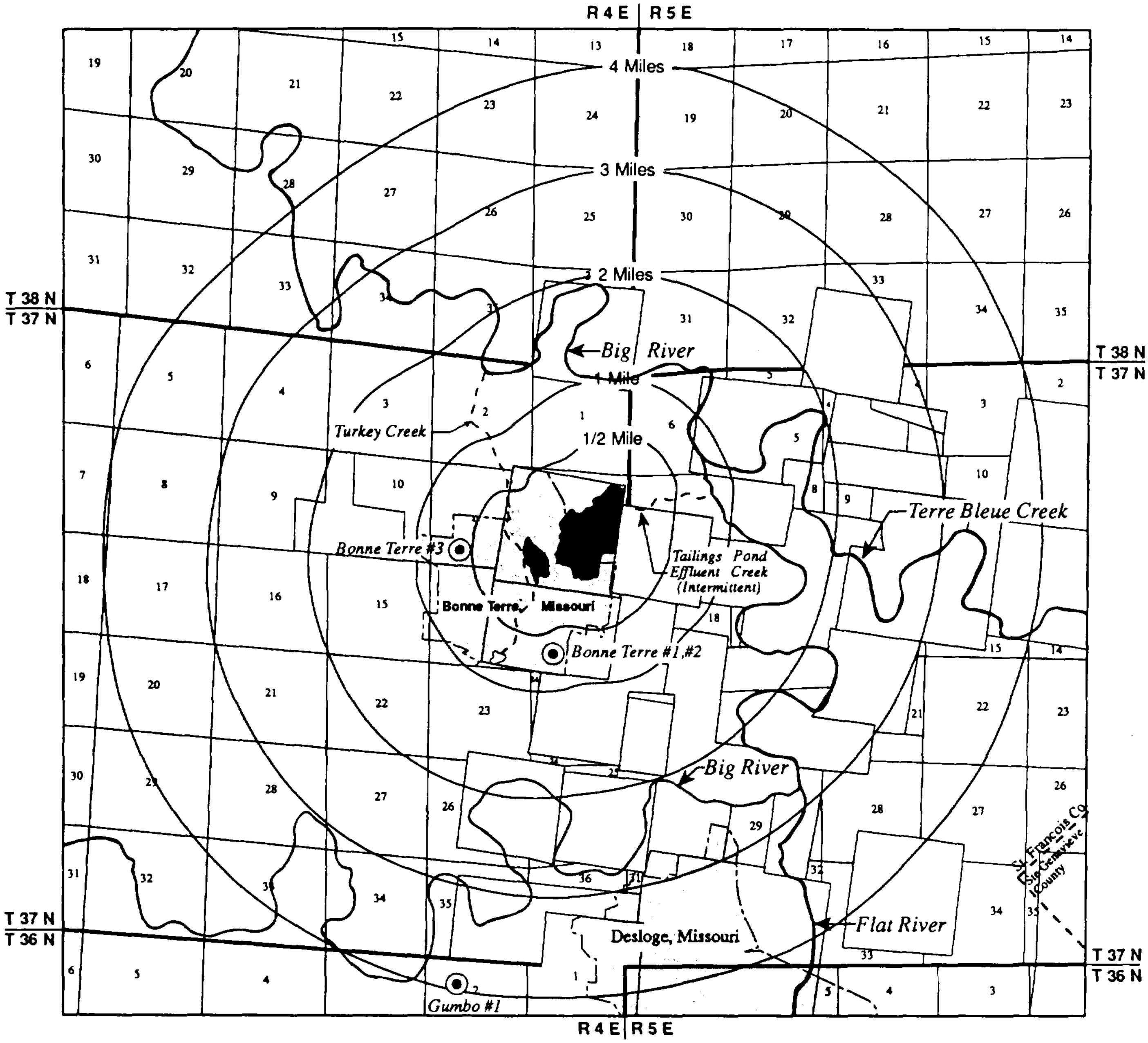


Source: Missouri Dept. Natural Resources:
Dept. of Geology and Land Survey (MDNR-DGLS) 1992;
U.S.G.S. 7.5' Bonne Terre (1982), French Village (1964),
Flat River (1982), Farmington (1982) Quadrangles.

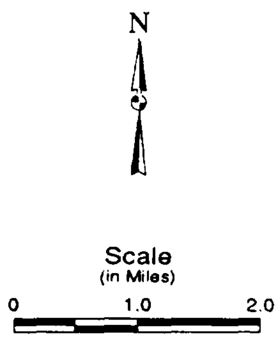
Project No.:	Bonne Terre Mine Tailings Bonne Terre, Missouri	2-Mile Radius Registered Wells	Figure
7760-013	CDM FEDERAL PROGRAMS CORPORATION a subsidiary of Camp Dresser & McKee Inc.		4-4
			1/93

TABLE 4-1
2-Mile Radius Registered Well Summary
Bonne Terre Mine Tailings
Bonne Terre, Missouri

Well No.	Location 1/4, 1/4, Section, Township, Range	Capacity (GPM)	Depth (Feet)	Static Water Level (Feet)	Use
1	SW, SE, Section 1, T37N, R4E	25	144	81	Unknown
2	SE, NW, Section 1, T37N, R4E	20	143	--	Domestic
3	Section 1, T37N, R4E	--	--	--	Domestic
4	SE, SW,Section 2, T37N, R4E	8	300	--	Domestic
5	Section 2, T37N, R4E	27	400	135	Domestic
6	Section 2, T37N, R4E	20	320	200	Domestic
7	SE, NE, Section 2, T37N, R4E	30	204	40	Unknown
8	SW, NE, Section 2, T37N, R4E	--	210	--	Domestic
9	NE, NW, Section 3, T37N, R4E	30	485	--	Domestic
10	NE, SW, Section 10, T37N, R4E	20	--	--	Domestic
11	SW, SW, Section 10, T37N, R4E	25	451	--	Domestic
12	SE, SW, Section 10, T37N, R4E	20	451	60	Dom estic
13	SE, SW, Section 10, T37N, R4E	12	223	60	Domestic
14	SW, NE, Section 11, T37N, R4E	20	205	60	Domestic
15	NW, NW, Section 11, T37N, R4E	20	205	70	Domestic
16	NW, NW, Section 11, T37N, R4E	30	164	--	D omestic
17	Section 12, T37N, R4E	60	430	100	Domestic
18	SE, NW, Section 13, T37N, R4E	45	413	140	Domestic
19	SW, NW, Section 14, T37N, R4E	30	204	50	Dom estic
20	SW, NW, Section 14, T37N, R4E	60	384	60	Domestic
21	NW, SW, Section 14, T37N, R4E	20	310	180	Unkown
22	NE, NW, Section 15, T37N, R4E	18	328	80	D omestic
23	SW, NE, Section 15, T37N, R4E	25	307	110	Domestic
24	Section 24, T37N, R4E	20	348	200	Domestic
25	Section 24, T37N, R4E	20	348	200	Domestic
26	NW, SE,Section 24, T37N, R4E	20	312	163	Domestic
27	Section 5, T37N, R5E	--	1 64	--	Domestic
28	Section 6, T37N, R5E	15	271	50	Domestic
29	NW, NE,Section 6, T37N, R5E	75	352	77	Domestic
30	Section 6, T37N, R5E	40	369	--	Domestic
31	SW, SW,Section 6, T37N, R5E	25	348	--	Domestic
32	Section 7, T37N, R5E	10	143	20	Domestic
33	Section 7, T37N, R5E	40	348	45	Domestic
34	NE, SE, Section 7, T37N, R5E	25	210	--	Unknown
35	NE, Section 7, T37N, R5E	30	164	--	Domestic
36	Section 7, T37N, R5E	5	328	--	Domestic
37	NW, NE, Section 7, T37N, R5E	20	164	4 0	Unknown
38	SE, NW, Section 7, T37N, R5E	60	312	72	Domestic
39	SE, NE, Section 7, T37N, R5E	50	348	60	Domestic



Source: City of Bonne Terre, Missouri 1992; J. Schumacker 1993; U.S.G.S. 7.5' Bonne Terre (1982), French Village (1964), Flat River (1982), Farmington (1982) Quadrangles.



Corporate Limits

Mine Tailings/Chat Deposits

Municipal Wells

Project No.: 7760-013	Bonne Terre Mine Tailings Bonne Terre, Missouri CDM FEDERAL PROGRAMS CORPORATION a subsidiary of Camp Dresser & McKee Inc.	Municipal Wells within 4-Mile Radius	Figure No.: 4-5 1/93

The community of Gumbo, Missouri, has one municipal well that serves approximately 124 persons located in the northwest quarter of section 2, township 36 N, Range 4 E (Figure 4-5). The Gumbo well lies within the 4-mile radius of the Bonne Terre site. The well is finished at a depth of 565 feet and is rated at 60 GPM. The static water level of the well is reported as 111 feet (Schumacher 1993).

There are no other known municipal wells in the 4-mile radius. Lake Timberline, a small lake development 3.5 miles to the north of Bonne Terre, is served by individual private wells (Robbins 1993).

Terre Du Lac, a small lake development 3.75 miles west of Bonne Terre, is supplied by three blended wells serving 910 households that area located outside the 4-mile radius. Residents outside the lake development rely on private well for drinking water (Tilley 1993).

Desloge, Missouri, approximately three miles south of Bonne Terre, is supplied water from the Flat River municipal system. Flat River is supplied water by a three well blended system with two primary wells and one standby well located in Desloge. The two primary wells are located outside the 4-mile radius of Bonne Terre (Warren 1993).

Water-bearing units in the Bonne Terre area are believed to be hydraulically connected based on Karst terrain and numerous interconnected mine shafts and drifts in the area.

5.0 PATHWAY ASSESSMENT

5.1 GROUNDWATER TARGETS

Soils in the Bonne Terre area are classified as the Caneyville-Crider-Gasconade association. These soils consist primarily of well-drained which formed from loess and clayey material. Their water capacity is low as well as their permeability. These soils act as an aquitard shielding the deeper aquifer of the Bonneterre and Lamotte Formations (USDA/SCS 1981). Never the less, due to karst terrain and the numerous mine shafts, it would be reasonable to believe that surface water infiltration to lower stratum would be highly likely under these conditions.

The City of Bonne Terre is serviced with three blended municipal wells. The community of Gumbo, Missouri, is serviced with a single well. The residents of Desloge, Missouri, are serviced by the Flat River municipal well system, which is located outside the 4-mile radius from the site. All other residents within a 4-mile radius of the site relies on private water wells for potable water.

Groundwater target information for the Bonne Terre area is very limited. A combination of limited well registrations and unknown well locations due to the French long-lot survey system common in the Bonne Terre area, have made target assessment difficult. As detailed in Section 4.2, there are 39 identifiable registered private wells within a 2-mile radius of Bonne Terre.

The U. S. Census 1990 Population Record for Bonne Terre, Missouri, is 3,819 persons. Municipal well apportionment places all 3,819 persons in the 1/2-mile to 1-mile radius zone from the site.

The community of Gumbo, Missouri has one municipal well that serves approximately 124 persons located in the northwest quarter of Section 2, Township 36 N, Range 4 E (Figure 4-5). The Gumbo well lies within the 4-mile radius of the Bonne Terre site. The well is finished at a depth of 565 feet and is rated at 60 GPM. The static water level of the well is reported as 111 feet (Schumacher 1993).

A rural target population was estimated by counting the number of dwellings indicated on USGS 7.5' topographic quadrangles and multiplying this figure by the St. Francois County average number of persons per household (2.59).

Based on the previously noted circumstances, the following groundwater drinking population apportionment was calculated: 0-1/4 mile: 46 rural persons, 1/4-1/2 mile: 303 rural persons, 1/2-1 mile: 422 rural residents + 3,819 Bonne Terre residents, 1-2 miles: 533 rural persons, 2-3 miles: 455 rural persons, 3-4 miles: 769 rural residents + 124 Gumbo, Missouri, residents. A total groundwater drinking population within 4-miles of the Bonne Terre Mine Tailings site is 6,471 persons.

Groundwater flow direction is not totally understood for the Bonne Terre area. Variations in groundwater flow patterns are influenced by topography, regional flow patterns, and local well drawn down effects, which are compounded by karst terrain and interconnected mine shafts (vertical tunnels) and drifts (horizontal tunnels) in the area. It would be reasonable to believe that the local groundwater flow would be following surface water trends to the northwest. The water bearing units in the Bonneterre and Lamotte formations are believed to be hydraulically connected due to the karst terrain and interconnected mine shafts and drifts in the area.

Despite the groundwater flow direction, a localized reversal or alteration in groundwater flow patterns could result from a drawdown effect created by numerous heavily used wells, private as well as municipal wells. With frequent use of water wells within a confined area, a cone of depression would have a spherical "zone of influence" surrounding the well. Groundwater within this zone would flow towards the well from all sides. Therefore, contaminants present in close proximity with the zone of influence would be drawn into the well.

5.2 SURFACE WATER TARGETS

There are no known surface water intakes along Turkey Creek or Big River within the area of concern associated with the Bonne Terre Mine Tailings site. Turkey Creek and Big River are utilized for recreation and as a local fishery (MGSWR 1967).

There are wildlife sensitive environments within a 4-mile radius from the site. A rare natural fen community is found within 3.3 miles from the site near wetlands. The Rigid sedge (Carex tetanica) occurs in this environment and is currently listed as endangered species status undetermined. Another fen natural community occurs at Coonville Creek Natural Area in St. Francois State Park (DNR) 3.8 miles from the site. This is classified as a rare community that includes the Tussock sedge (Carex stricta), state listed rare, sedge (Carex sterilis), state listed endangered, and queen of the prairie (Filipendula ruba), state listed endangered, all occur in this fen wetland environment. Additionally, St. Francois State Park is located 9.5 miles from the site downstream along Big River (Dickneite 1992).

Surface drainage for the chat pile follows natural erosion routes towards the northwest as intermittent streams which feed into Turkey Creek (CDM Federal 1992). Turkey Creek is located approximately 200 feet west of the chat pile and flows from south to north at an unknown flow rate (CDM Federal 1992, Malone 1993). Turkey Creek meets Big River approximately 10,600 feet north of Bonne Terre, Missouri. Bonne Terre Mine Tailings site is within the 100-year flood plain (FEMA 1985).

Surface drainage for the tailings field is controlled by an impoundment dam to the north and east boundaries of the field. Overland flow for the field follows a south to north trend. A tailings pond is located at the north end of the field which covers approximately five surface acres and ranges in depth from two to four feet deep (Black 1993). Excess water from the tailings pond is routed through a decanting tower located at the north end of the tailings pond. Water released from the pond flows east via intermittent stream approximately 5,700 feet to the Big River.

Big River is the major surface water river in the Bonne Terre area. Flat River (south), Terre Bleue Creek (east), the tailings pond effluent creek (east), and Turkey Creek (south) all join the Big River within a 4-mile radius of the site. Big River has and annual average flow rate of 187 cfs measured at Irondale, Missouri, and an annual average flow rate of 692 cfs measured downstream at Richwood, Missouri (Malone 1993).

A release of contaminants to surface water is suspected. Overland flow to surface water is approximately 200 feet. Surface water contamination attributed to mine tailings deposits of the Old Lead Belt have been observed in past studies of the area (Haas 1986, Trial 1985, Wixson 1982 and 1983). Surface water drainage routes are well defined (CDM Federal 1992). During the site reconnaissance, December 14-16, 1992, the Bonne Terre area received light to moderate rainfall. Surface water drainage routes were visibly noted. Surface runoff was discolored after leaving the chat pile site (gray/brown color) (CDM Federal 1992).

5.3 SOIL EXPOSURE ASSESSMENT

Currently the chat pile is unrestricted to public access, however, is fenced on the east side. The tailings field is fenced on all sides, however, there have been numerous accounts of trespassing regardless of any preventative measures taken on both sites (CDM Federal 1992). The ground cover surrounding the chat pile may have been stressed, however, reconnaissance activities occurred during the month of December, a dormant growth period. Vegetation on the chat pile and tailings field was absent, excluding five seeded acres at the south end of the tailings field. Ground cover in the area is primarily gravel (chat) with a fine clayey/sandy sediment (possibly eroded tailings). The soil at Bonne Terre is primarily a silty clay loess with low permeability (USDA/SCS 1981).

The nearest residence to the site is approximately 200 feet to the west of the chat pile on Young street in Bonne Terre, Missouri. There are at least five residences (approximately 15 persons) within 200 feet of the chat pile debris at this location. The closest residence towards the east is approximately 200 feet from the chat pile on Hazel street in Bonne Terre. There are at least four homes (approximately 12 persons) at this location. The Leadbelt Golf Course is located to the north of the site. Commercial businesses are primarily located to the south of the site (CDM Federal 1992). North County Elementary School is adjacent to the chat pile towards the west. There are 1,032 students enrolled at the school in grades kindergarten through 6th grade. There are 60 teachers and staff onsite at the school (Aubuchon 1993). The school playground is less than 200 feet from the chat pile. No known daycare facilities are located within 200 feet of the site.

There are terrestrial sensitive environments associated with the rare fen communities discussed in Section 5.2. Additionally, St. Joe State Park is located 3/4 mile south of the site (Dickneite 1992).

Soil exposure has been identified at this site through the sampling activities conducted by the University of Missouri - Rolla in 1983. Contaminants associated with both potential sources are heavy metals, specifically lead cadmium and zinc. Elevated concentrations of lead, cadmium and zinc were identified in both the chat pile and tailings field. Due to the high toxicity and mobility of the contaminates involved, the potential for exposure to groundwater, surface water, and air (blowing dust) via contaminated soil (mine deposits), are high at this site.

5.4 AIR PATHWAY TARGETS

The air pathway is of concern specifically with the tailings field deposits. Due to the nature of the fine milling process of the tailings, fine sediments are subject to blowing during the dry periods of the year (Black 1993). According to Damon Black (1993), when the wind blows from the southwest to the northeast during the dry months in the summer, the severity of the blowing sediment is so that visibility is less than 10 feet if you are within the blowing sediments. Black estimates that the airborne sediments continue northeast approximately one mile from the site. Efforts have been made in stabilizing the tailings field. Approximately five acres in the south end of the tailings field has been seeded (Black 1992).

Potential air target population estimates were calculated in the same manner as the groundwater drinking population discussed in Section 5.1. The potential population of Desloge, Missouri was included in the estimate in the event wind patterns shifted to the south. Desloge was estimated as having 70% of its population within a 4-mile radius of the site equating to approximately 2,831 persons. Based on the previously stated circumstances, the following potential air target apportionment was calculated: 0-1/4 mile: 618 persons, 1/4-1/2 mile: 684 persons, 1/2-1 mile 3,095 persons, 1-2 miles: 723 persons, 2-3 miles: 453 persons, and 3-4 miles: 3,600 persons. The total number of potential air pathway targets within a 4-mile radius of the Bonne Terre Mine Tailings site is 9,173 persons.

6.0 SUMMARY AND CONCLUSION

Based on analytical data of surface soil sampling activities collected by the University of Missouri-Rolla in 1983, a significant level of hazardous substances in the mine deposits does exist. Elevated concentrations of lead, cadmium, and zinc were identified in both the chat pile and tailings field. Additionally, studies conducted in the Bonne Terre area have attributed mine tailings to surface water (Big River), fish, and environmental contamination (Haas 1986; Trial 1985; Wixson 1982, 1983).

The chat pile and the tailings field are poorly contained and have been documented to have been accessible to the public throughout the years.

There are no identified primary targets in the groundwater, surface water and air pathways, however, supportive information that may identify primary targets was limited. Primary targets have been identified in the soil exposure pathway. Residential areas are located on the east and west sides of the chat pile. North County Elementary school is adjacent to the west of the chat pile.

Groundwater flow direction is unclear. It would appear that groundwater flows with a topographic influence thus directing groundwater flow to the northwest. Effects of karst terrain are expected in the Bonne Terre area. There are numerous interconnected mine shafts and drifts common in the area, thus influencing unrestricted surface water/groundwater exchange and flow.

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APPENDIX A

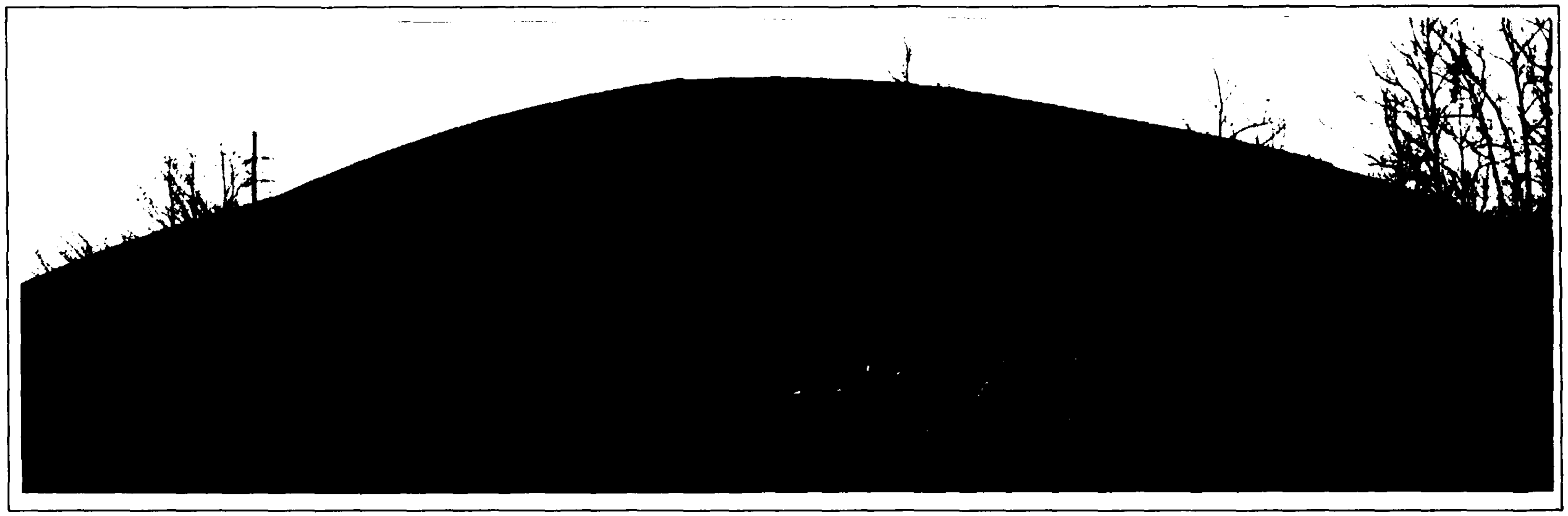
Photographic Documentation Log

Photographic Record

CDM FEDERAL PROGRAMS CORPORATION
a subsidiary of Camp Dresser & McKee Inc.

Site Name: Bonne Terre Mine Tailings
CERCLIS ID No.: MOD985818236
Site Location: Bonne Terre, MO (St. Francois Co.)
Work Assignment No.: 013-79ZZ
Project Reference No.: 7760-013-SM2-BTMT

No. 1
Description:
Chat pile with erosional tailings located south of the Leadbelt Golf Course. (panoramic).
Photographer:
Jeff J. Weatherly
Witness:
Laura Splichal
Date / Time:
12/15/92 1510 hrs.
Direction:
West

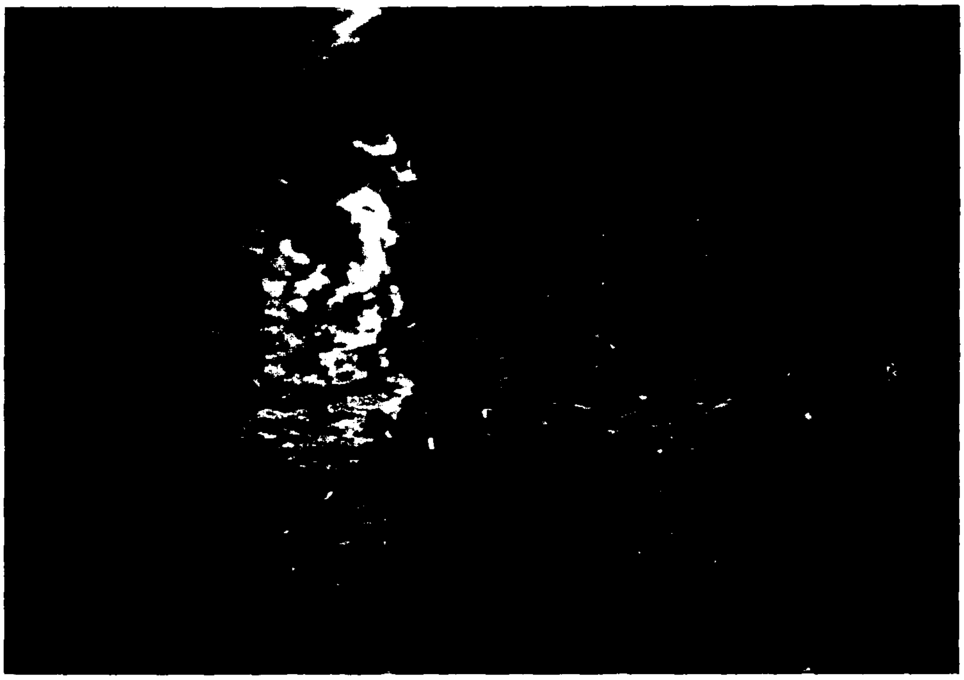


No. 2
Description:
Chat pile viewed from the old Missouri Illinois railroad access road (panoramic).
Photographer:
Jeff J. Weatherly
Witness:
Laura Splichal
Date / Time:
12/15/92 0945 hrs.
Direction:
North

Photographic Record

CDM FEDERAL PROGRAMS CORPORATION
a subsidiary of Camp Dresser & McKee Inc.

Site Name:
Bonne Terre Mine Tailings
CERCLIS ID No.:
MOD985818236
Site Location:
Bonne Terre, MO
(St. Francois County)
Work Assignment No.:
013-79ZZ
Project Reference No.:
7760-013-SM2-BTMT



No. 5
Description:
(Above Right) Surface drainage from the chat pile follows routes of erosion and service roads. Diamond bit core samples litter the ground in the northern portion of the chat pile erosional deposits.

Photographer: Jeff J. Weatherly
Date / Time: 12/15/92 1538 hrs.
Witness: Laura Splichal
Direction: West

No. 6
Description:
(Right) Surface drainage from the tailings located north of the chat pile. Surface water discoloration indicates an observed release of tailings material.

Photographer: Jeff J. Weatherly
Date / Time: 12/15/92 1535 hrs.
Witness: Laura Splichal
Direction: South

Photographic Record

CDM FEDERAL PROGRAMS CORPORATION
a subsidiary of Camp Dresser & McKee Inc.

Site Name:	Bonne Terre Mine Tailings
CERCLIS ID No.:	MOD985818236
Site Location:	Bonne Terre, MO (St. Francois County)
Work Assignment No.:	013-79ZZ
Project Reference No.:	7760-013-SM2-BTMT

No. 7
Description:
Turkey Creek viewed from Benham Street. Turkey Creek flows approximately 10,600 feet north from the site to the Big River. Overland flow to the creek is approximately 200 feet from the site.
Photographer:
Jeff J. Weatherly
Witness:
Laura Splichal
Date / Time:
12/15/92 1540 hrs.
Direction:
North

No. 8
Description:
An aerial photograph taken in 1987. Chat pile is identified on the left, tailings field on the right. North is the top of the photograph. (photo-reproduced)
Photographer:
Jeff J. Weatherly
Witness:
Laura Splichal
Date / Time:
12/15/92 1445 hrs.
Direction:
North is top of photo

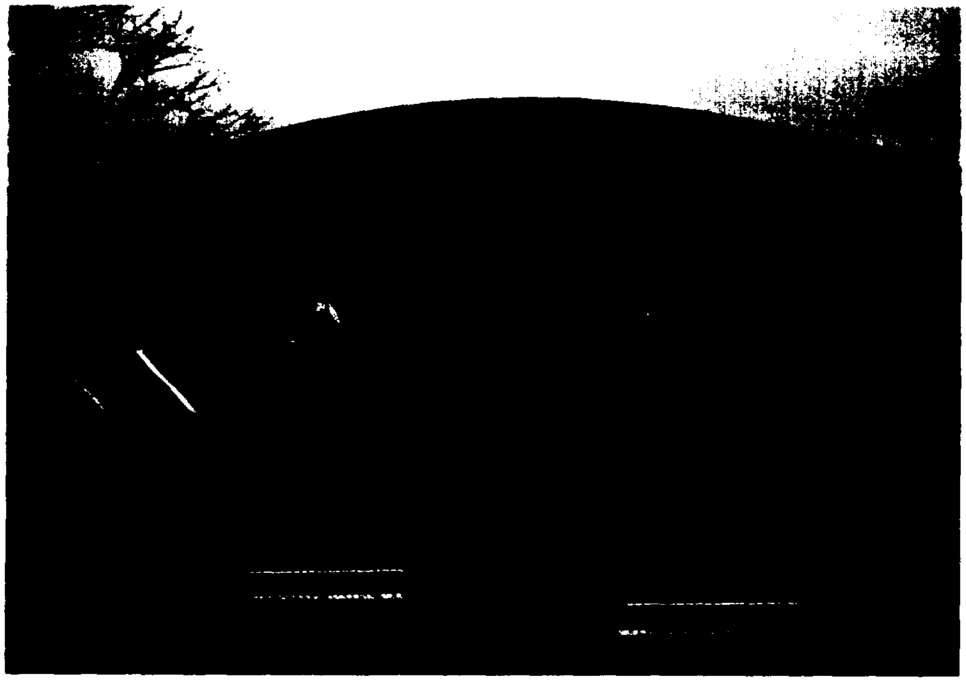
Scale
(feet)
0 2400

Photo Source: City of Bonne Terre, Missouri 1992

Photographic Record

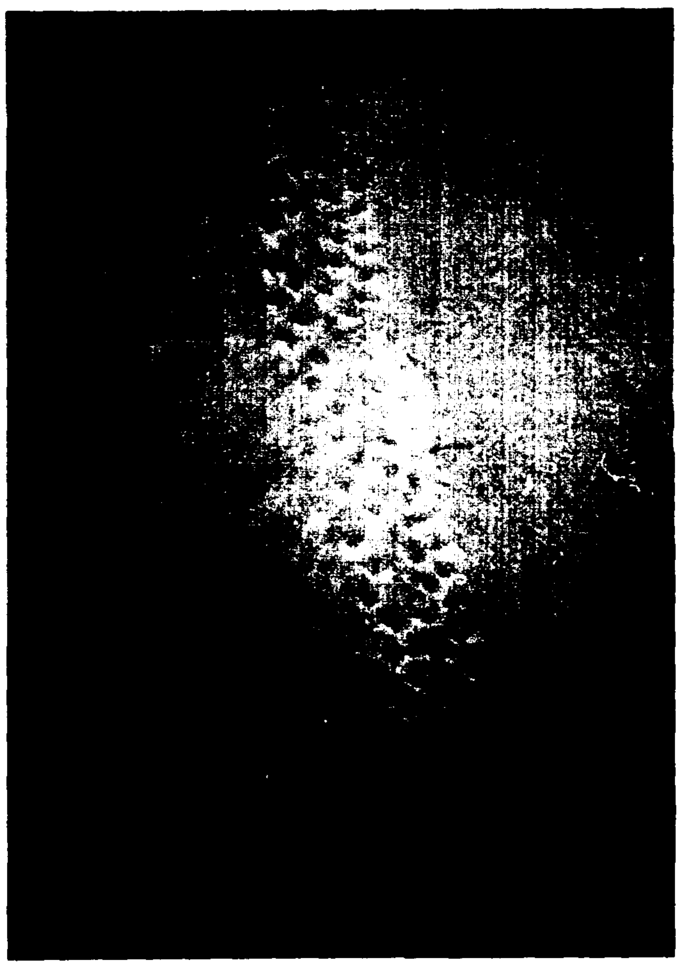
CDM FEDERAL PROGRAMS CORPORATION
a subsidiary of Camp Dresser & McKee Inc.

Site Name:
Bonne Terre Mine Tailings
CERCLIS ID No.:
MOD985818236
Site Location:
Bonne Terre, Missouri
(St. Francois County)
Work Assignment No.:
013-79ZZ
Project Reference No.:
7760-013-SM2-BTMT



No. 3
Description:
(Above Right) Chat pile viewed from the North County Elementary School grounds. The school is located west of the chat pile. The playground area is bordered by chat/tailings debris to the east. The school has 1,032 students kindergarten through 6th grade.

Photographer:	**Date / Time:**
Jeff J. Weatherly	12/15/92 1540 hrs.
Witness:	**Direction:**
Laura Splichal	NE



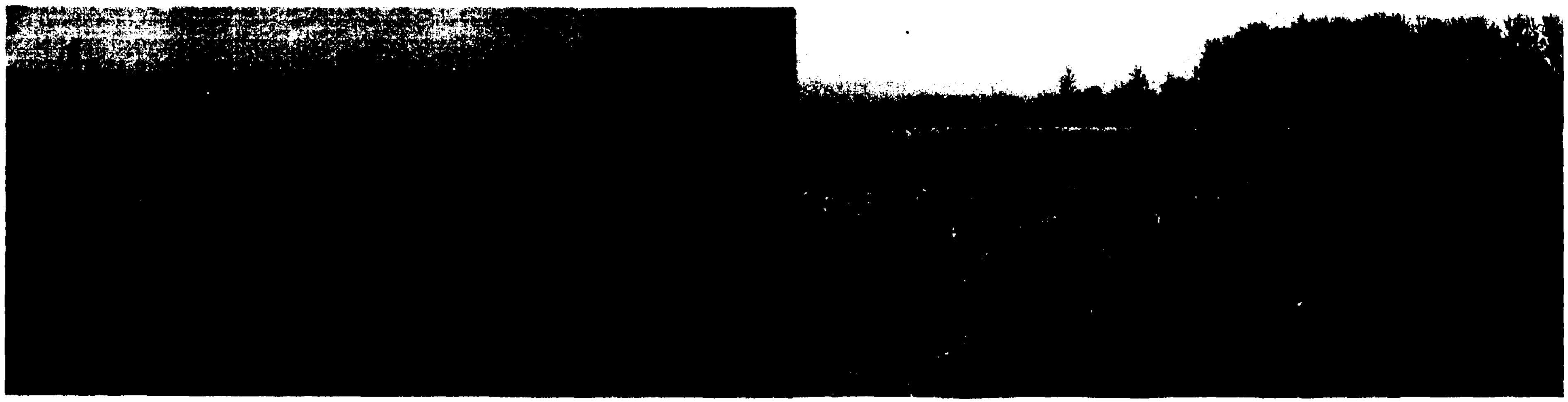
No. 4
Description:
(Right) Footprints in the chat pile offer evidence of unrestricted public access.

Photographer:	**Date / Time:**
Jeff J. Weatherly	12/15/92 0940 hrs.
Witness:	**Direction:**
Laura Splichal	West

Photographic Record

CDM FEDERAL PROGRAMS CORPORATION
a subsidiary of Camp Dresser & McKee Inc.

Site Name: Bonne Terre Mine Tailings
CERCLIS ID No.: MOD985818236
Site Location: Bonne Terre, MO (St. Francois Co.)
Work Assignment No.: 013-79ZZ
Project Reference No.: 7760-013-SM2-BTMT



No. 9
Description:
(ABOVE) Tailings field (panoramic). Mr. Damon Black of Bonne Terre, Missouri, principal owner of the tailings field, has seeded approximately 5 acres of the tailings field. The seeded portion requires annual fertilizing due to the lack of nutrients to support vegetation.
Photographer:
Jeff J. Weatherly
Witness:
Doug Updike
Date / Time:
12/16/92 1037 hrs.
Direction:
West

No. 10
Description:
(RIGHT) Tailings field. Most of the tailings at Bonne Terre are barren dune-like material, medium to fine grained sand. Less than 3% of the tailings field is vegetated. The Bonne Terre chat pile can be seen in the background, east of the tailings.
Photographer:
Jeff J. Weatherly
Witness:
Doug Updike
Date / Time:
12/16/92 1138 hrs.
Direction:
East

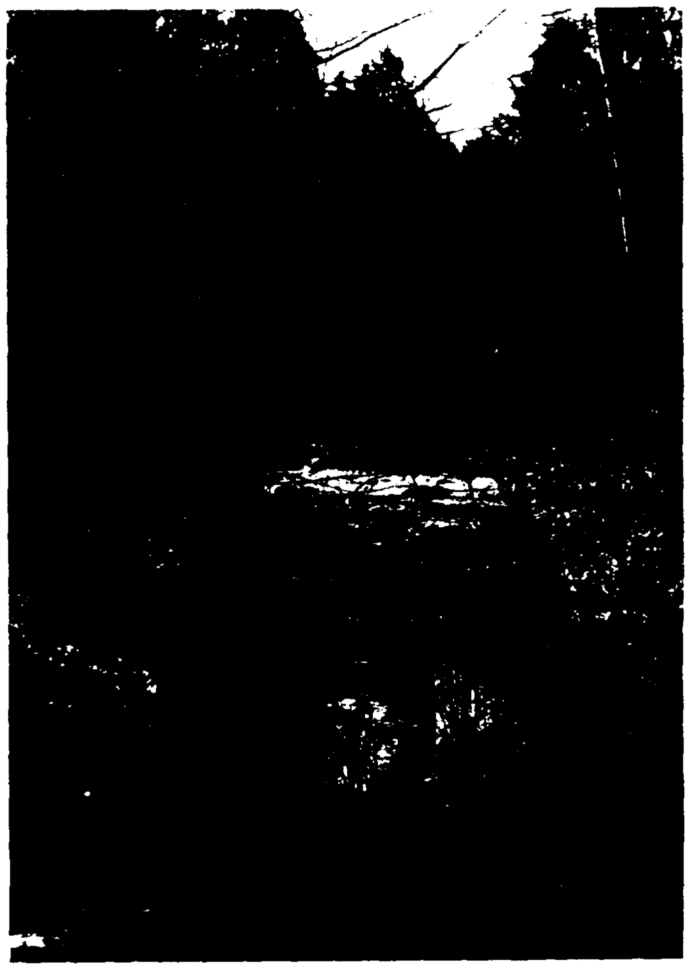
Photographic Record

CDM FEDERAL PROGRAMS CORPORATION
a subsidiary of Camp Dresser & McKee Inc.

Site Name:
Bonne Terre Mine Tailings
CERCLIS ID No.:
MOD985818236
Site Location:
Bonne Terre, MO
(St. Francois County)
Work Assignment No.:
013-79ZZ
Project Reference No.:
7760-013-SM2-BTMT

No. 11
Description:
(Above Right) Tailings pond located at the north end of the tailings field. Estimated depth of pond is between 2 and 4 feet. Pond covers approximately 5 surface acres according to the property owner, Mr. Damon Black.

Photographer:	**Date / Time:**
Jeff J. Weatherly	12/16/92 1112 hrs.
Witness:	**Direction:**
Doug Updike	South



No. 12
Description:
(Right) Surface drainage from the tailings field is routed through a decanting tower and released on the north side of the impoundment. The effluent creek flows easterly approximately 5,700 feet to the Big River.

Photographer:	**Date / Time:**
Jeff J. Weatherly	12/16/92 1201 hrs.
Witness:	**Direction:**
Doug Updike	West

APPENDIX B

USEPA Preliminary Assessment Form

EPA Potential Hazardous Waste Site Preliminary Assessment Form

Identification

State:	CERCLIS Number:
MO	MOD985818236

CERCLIS Discovery Date:

1. General Site Information

Name: Bonne Terre Mine Tailings		Street Address: Hwy 47 and Hwy 67				
City: Bonne Terre		State: MO	Zip Code: 63628	County: St. Francois	Co. Code:	Cong. Dist.
Latitude: 37 ° 55 ' 50._"	Longitude: 90 ° 32 ' 22._"	Approximate Area of Site: 322 Acres ____ Square Ft		Status of Site: ☐ Active ■ Inactive ☐ Not Specified ☐ NA (GW plume, etc.)		

2. Owner/Operator Information

Owner: St. Joe Minerals / Joe Tucker	Damon Black
Street Address: -Chat Pile Owner- 3333 Michelson Dr.	Street Address: Principal Tailings Owner Rt. 1 Box 38
City: Irvine	City: Bonne Terre
State: CA Zip Code: 92730 Telephone: (714) 975-4989	State: MO Zip Code: 63628 Telephone: (314) 358-3136

Type of Ownership:
- ■ Private
- ☐ Federal Agency Name ________
- ☐ State
- ☐ Indian
- ☐ County
- ☐ Municipal
- ☐ Not Specified
- ☐ Other ________

How Initially Identified:
- ☐ Citizen Complaint
- ☐ PA Petition
- ☐ State/Local Program
- ☐ RCRA/CERCLA Notification
- ☐ Federal Program
- ☐ Incidental
- ☐ Not Specified
- ■ Other SACM

3. Site Evaluator Information

Name of Evaluator: Jeff J. Weatherly	Agency/Organization: CDM Federal	Date Prepared: January 29, 1993
Street Address: 8215 Melrose Dr., Suite 100	City: Lenexa	State: KS
Name of EPA or State Agency Contact: Region VII EPA Greg Ressor	Street Address: 726 Minnesota Ave.	
City: Kansas City	State: KS	Telephone: (913) 551-7695

4. Site Disposition (for EPA use only)

Emergency Response/Removal Assessment Recommendation:
- ☐ Yes
- ☐ No
- Date: ________

CERCLIS Recommendation:
- ☐ Higher Priority SI
- ☐ Lower Priority SI
- ☐ NFRAP
- ☐ RCRA
- ☐ Other ________
- Date: ________

Signature:

Name (typed):

Position:

EPA Potential Hazardous Waste Site
Preliminary Assessment Form - Page 2 of 4

CERCLIS Number: MOD985818236

5. General Site Characteristics

Predominant Land Uses Within 1 Mile of Site (check all that apply):

- ☐ Industrial
- ☐ Commercial
- ☐ Residential
- ☐ Forest/Fields
- ■ Agriculture
- ■ Mining
- ☐ DOD
- ☐ DOE
- ☐ DOI
- ☐ Other Federal Facility
- ■ Other Tourism

Site Setting:

- ■ Urban
- ☐ Suburban
- ☐ Rural

Years of Operation:

Beginning Year 1864
Ending Year 1961
☐ Unknown

Type of Site Operations (check all that apply):

- ☐ Manufacturing (must check subcategory)
  - ☐ Lumber and Wood Products
  - ☐ Inorganic Chemicals
  - ☐ Plastic and/or Rubber Products
  - ☐ Paints, Varnishes
  - ☐ Industrial Organic Chemicals
  - ☐ Agricultural Chemicals (e.g., pesticides, fertilizers)
  - ☐ Miscellaneous Chemical Products (e.g., adhesives, explosives, ink)
  - ☐ Primary Metals
  - ☐ Metal Coating, Plating, Engraving
  - ☐ Metal Forging, Stamping
  - ☐ Fabricated Structural Metal Products
  - ☐ Electronic Equipment
  - ☐ Other Manufacturing
- ■ Mining
  - ■ Metals (lead)
  - ☐ Coal
  - ☐ Oil and Gas
  - ☐ Non-metallic Minerals
- ☐ Retail
- ☐ Recycling
- ☐ Junk/Salvage Yard
- ☐ Municipal Landfill
- ☐ Other Landfill
- ☐ DOD
- ☐ DOE
- ☐ DOI
- ☐ Other Federal Facility ______
- ☐ RCRA
  - ☐ Treatment, Storage, or Disposal
  - ☐ Large Quantity Generator
  - ☐ Small Quantity Generator
  - ☐ Subtitle D
    - ☐ Municipal
    - ☐ Industrial
  - ☐ "Converter"
  - ☐ "Protective Filer"
  - ☐ "Non- or Late Filer"
- ☐ Not Specified
- ☐ Other ______

Waste Generated:

- ☐ Onsite
- ☐ Offsite
- ■ Onsite and Offsite

Waste Deposition Authorized By:

- ■ Present Owner
- ■ Former Owner
- ☐ Present & Former Owner
- ☐ Unauthorized
- ☐ Unknown

Waste Accessible to the Public:

- ■ Yes
- ☐ No

Distance to Nearest Dwelling, School, or Workplace: 200 Feet

6. Waste Characteristics Information

Source Type: (check all that apply)	Source Waste Quantity: (include units)	Tier*:
☐ Landfill		
■ Surface Impoundment	160 ac	A
☐ Drums		
☐ Tanks and Non-Drum Containers		
☐ Chemical Waste Pile		
☐ Scrap Metal or Junk Pile		
■ Tailings Pile	32 ac	A
☐ Trash Pile (open dump)		
☐ Land Treatment		
☐ Contaminated Ground Water Plume (unidentified source)		
☐ Contaminated Surface Water/Sediment (unidentified source)		
☐ Contaminated Soil		
☐ Other ______		
☐ No Sources		

* C = Constituent, W = Wastestream, V = Volume, A = Area

General Types of Waste (check all that apply)

- ■ Metals
- ☐ Organics
- ☐ Inorganics
- ☐ Solvents
- ☐ Paints/Pigments
- ☐ Laboratory/Hospital Waste
- ☐ Radioactive Waste
- ☐ Construction/Demolition Waste
- ☐ Pesticides/Herbicides
- ☐ Acids/Bases
- ☐ Oily Waste
- ☐ Municipal Waste
- ☐ Mining Waste
- ☐ Explosives
- ☐ Other ______

Physical State of Waste as Deposited (check all that apply):

- *■ Solid
- ☐ Sludge
- ☐ Powder
- ☐ Liquid
- ☐ Gas

*gravel 3/8" or less down to med/fine sand

EPA Potential Hazardous Waste Site
Preliminary Assessment Form - Page 3 of 4

CERCLIS Number: MOD985818236

7. Ground Water Pathway

Is Ground Water Used for Drinking Water Within 4 Miles:
- ■ Yes
- ☐ No

Type of Drinking Water Wells Within 4 Miles (check all that apply):
- ■ Municipal
- ■ Private
- ☐ None

Depth to Shallowest Aquifer: 143 Feet

Karst Terrain/Aquifer Present:
- ■ Yes
- ☐ No

Is There a Suspected Release to Ground Water:
- ■ Yes
- ☐ No

Have Primary Target Drinking Water Wells Been Identified:
- ☐ Yes
- ■ No

If Yes, Enter Primary Target Population: N/A People

Nearest Designated Wellhead Protection Area:
- ☐ Underlies Site
- ☐ >0 - 4 Miles
- ■ None Within 4 Miles

List Secondary Target Population Served by Ground Water Withdrawn From:

0 - ¼ Mile	46
> ¼ - ½ Mile	303
> ½ - 1 Mile	4,241
> 1 - 2 Miles	533
> 2 - 3 Miles	455
> 3 - 4 Miles	893
Total Within 4 Miles	6,471

8. Surface Water Pathway

Type of Surface Water Draining Site and 15 Miles Downstream (check all that apply):
- ■ Stream ■ River ☐ Pond ☐ Lake
- ☐ Bay ☐ Ocean ☐ Other ________

Shortest Overland Distance From Any Source to Surface Water:
200 Feet
____ Miles

Is There a Suspected Release to Surface Water:
- ■ Yes
- ☐ No

Site is Located in:
- ☐ Annual - 10 yr Floodplain
- ■ > 10 yr - 100 yr Floodplain
- ☐ > 100 yr - 500 yr Floodplain
- ☐ > 500 yr Floodplain

Drinking Water Intakes Located Along the Surface Water Migration Path:
- ☐ Yes
- ■ No

Have Primary Target Drinking Water Intakes Been Identified:
- ☐ Yes
- ■ No

If Yes, Enter Population Served by Primary Target Intakes: N/A People

List All Secondary Target Drinking Water Intakes:

Name	Water Body	Flow (cfs)	Population Served
No Known Surface Water Intakes			

Total within 15 Miles ________

Fisheries Located Along the Surface Water Migration Path:
- ■ Yes
- ☐ No

Have Primary Target Fisheries Been Identified:
- ■ Yes
- ☐ No

List All Secondary Target Fisheries:

Water Body/Fishery Name	Flow (cfs)
Turkey Creek	(less than) 100
Big River	187

8. Surface Water Pathway (continued)

Wetlands Located Along the Surface Water Migration Path:
■ Yes
☐ No

Have Primary Target Wetlands Been Identified:
Yes
■ No

List Secondary Target Wetlands:

Water Body	Flow (cfs)	Frontage Miles
Turkey Creek	(under)100	Unk
Big River	187	Unk

Other Sensitive Environments Located Along the Surface Water Migration Path:
■ Yes
☐ No

Have Primary Target Sensitive Environments Been Identified:
☐ Yes
■ No

List Secondary Target Sensitive Environments:

Water Body	Flow (cfs)	Sensitive Environment Type
Turkey Creek	(under 100)	riparian
Big River	187	

9. Soil Exposure Pathway

Are People Occupying Residences or Attending School or Daycare on or Within 200 Feet of Areas of Known or Suspected Contamination:
■ Yes
☐ No

If Yes, Enter Total Resident Population:
1,059 People

Number of Workers
☐ None
■ 1 - 100
☐ 101 - 1,000
☐ >1,000

(60 teacher/staff at the elementary school)

Have Terrestrial Sensitive Environments Been Identified on or Within 200 Feet of Areas of Known or Suspected Contamination:
☐ Yes
■ No

If Yes, List Each Terrestrial Sensitive Environment:

10. Air Pathway

Is There a Suspected Release to Air:
■ Yes
☐ No

Enter Total Population on or Within:

Onsite	0
0 - ¼ Mile	618
> ¼ - ½ Mile	684
> ½ - 1 Mile	3,095
> 1 - 2 Miles	723
> 2 - 3 Miles	453
> 3 - 4 Miles	3,600
Total Within 4 Miles	9,173

Wetlands Located Within 4 Miles of the Site:
■ Yes
☐ No

Other Sensitive Environments Located Within 4 Miles of the Site:
■ Yes
☐ No

List All Sensitive Environments Within ½ Mile of the Site:

Distance	Sensitive Environment Type/Wetlands Area (acres)
Onsite	None
0 - ¼ Mile	Possible riparian/terrestrial
> ¼ - ½ Mile	"

APPENDIX C

Referenced Citations

CDM Federal Programs Corporation

RECORD OF COMMUNICATION

[X] TELEPHONE CONVERSATION　　DATE: December 1, 1992

[ ] INCOMING　[X] OUTGOING　　TIME: 10:25 hrs

[ ] MEETING　　RECORDED BY: Jeff J. Weatherly

PROJECT: Bonne Terre Mine (SACM)　　CONTRACT NO.: 7760-013-SM2-BTMT

SUBJECT: Site Access, general background information

PARTICIPANTS	ORGANIZATION/DEPARTMENT	TELEPHONE NO./EXT.
Damon Black	Landowner	(314) 358-3136
Jeff J. Weatherly	CDM Federal	(913) 492-8181

SUMMARY:

Mr. Black had returned my call and left a message with CDM Federal receptionist (Stephanie) @ 1020 hrs. today. I return Mr. Black's call at 1025 hrs. I introduced myself and explained the CDM/EPA objectives. Mr. Black is the Land Assessor for that area. He said the area we will be interested in is U.S. Survey 3099. The actual water of the tailings pond is only about 5 surface acres, and less than 2 feet deep. There are two ponds. The second pond has been there for over one hundred years and is not associated with the tailings, however, is still in the area. Mr. Black said a major problem is the dust. During periods of dry weather and gusty winds, the dust from the tailing piles blows freely. Mr. Black said that they have seeded about 5 acres which is now more like 7 acres (grows every year), which has helped in reducing the dust blowing. According to Black the land was originally purchased from St. Joe Minerals and the deed states that the "air space" above the land is still owned by St. Joe Minerals. Black said the land is theirs, but the dust is St. Joe Minerals. Black said that there is about an 30 acre track on the west side of highway 67 that is owned by Marty Berry (widow to C.H. Berry). Her property is built on the tailings too. Paul L. McDowell is Black's partner and they own approx. 230 acres in this area. Mr. Black said he did not care if we came out and looked at the property. If we could call him ahead of time, he would meet us at the cafe at the intersection of highways 67 and 47. He could bring a plat map of the area and let us in on his property, if we lock the gate when we leave. Mr. Black said he thought that Paul McDowell would not care if we look around either. I said I would get a site access letter out to him this week.-END OF CONVERSATION-

DISTRIBUTION: [ ] PARTICIPANTS　[X] FILE　　INFORMATION　ACTION

OTHER: Major landowner. Land Assessor for that area. Good Contact for information. Call before the recon to make arrangements to meet him.

1/30/92　　File No.: 004

CDM Federal Programs Corporation

RECORD OF COMMUNICATION

[X] TELEPHONE CONVERSATION

[ ] INCOMING [X] OUTGOING

[ ] MEETING

DATE: January 28, 1993

TIME: 1520:00 hrs

RECORDED BY: Jeff J. Weatherly

PROJECT: Bonne Terre Mine (SACM)

CONTRACT NO.: 7760-013-SM2-BTMT

SUBJECT: Tailings Field Background Information

PARTICIPANTS	ORGANIZATION/DEPARTMENT	TELEPHONE NO./EXT.
Damon Black	Principal Tailings Field Owner	(314) 358-3136
Jeff J. Weatherly	CDM Federal	(913) 492-8181

SUMMARY:

Called to verify and gather additional tailings field/area information. Sybil Counts owns 14 acres just north of the chat pile. John McCullough verbally leases the 300' drag strip from Black. Runs in the summer months. Thickness of the tailings is from 0 (south end) to 50'thick on north end. Wind really blows the fine tailings during the dry summer months. If you were standing in the blowing sediments, you would not be able to see 10 feet, kinda like an Oklahoma dust storm. Sediments airborne are estimated to blow 1 mile away. Excavated tailings were hauled away for footing and foundation fill material and ag lime throughout the Bonne Terre area. Excavation of the tailings has been going on for the past 75 years. The tailings lake is approximately 5 surface acres ranging in depth from 2 to 4'. Drainage of the tailings field is south to north. In 1965-67 the tailings field was flooded and made into a ski beach. Water was pumped from St. Joe mine shaft No. 4 via 10" pipe to the tailings field. Tailings pond was drained via decanting tower to present level after ski beach business was not economically feasible. Tailings field is about 160 acres. Mr. Black is the elected St. Francois County Tax Accessor. Mr. Black wishes to develop the tailings field into commercial and residential by capping the tailings with asphalt and dirt, however, the funding for such an activity is scarce. Mary Berry owns 25+ acres between the tailing field and the chat pile. That pile is being excavated and hauled away. It is unknown as to where it is being hauled to.-END OF CONVERSATION-

DISTRIBUTION: [ ] PARTICIPANTS [X] FILE INFORMATION ACTION

OTHER: A LOT OF INFORMATION CONCERNING THE TAILINGS FIELD AND HISTORY.

Jeff Weatherly

1/30/92

File No.: 006

CDM Federal Programs Corporation

RECORD OF COMMUNICATION

[X] TELEPHONE CONVERSATION

[ ] INCOMING [X] OUTGOING

[ ] MEETING

DATE: January 28, 1993

TIME: 1535:00 hrs

RECORDED BY: Jeff J. Weatherly

PROJECT: Bonne Terre Mine (SACM)

CONTRACT NO.: 7760-013-SM2-BTMT

SUBJECT: Elementary school Information

PARTICIPANTS	ORGANIZATION/DEPARTMENT	TELEPHONE NO./EXT.
Mary Aubuchon	Secretary, North Co. Elem. School	(314) 358-2281
Jeff J. Weatherly	CDM Federal	(913) 492-8181

SUMMARY:

1,032 Students enrolled kindergarten through 6th grade. 60 Faculty/Staff at the school. There are two recess times daily, weather permitting, one at noon for 1/2 hour and the other in the afternoon for 1/4 hour.-END OF CONVERSATION-

DISTRIBUTION: [ ] PARTICIPANTS [X] FILE INFORMATION ACTION

OTHER: 1,032 Students

60 Staff

2 recesses daily total of 3/4 hour.

1/30/92

File No.: 007

CDM Federal Programs Corporation

RECORD OF COMMUNICATION

[X] TELEPHONE CONVERSATION

[ ] INCOMING [X] OUTGOING

[ ] MEETING

DATE: January 28, 1993

TIME: 1547:00 hrs

RECORDED BY: Jeff J. Weatherly

PROJECT: Bonne Terre Mine (SACM)

CONTRACT NO.: 7760-013-SM2-BTMT

SUBJECT: Bonne Terre Water information

PARTICIPANTS	ORGANIZATION/DEPARTMENT	TELEPHONE NO./EXT.
Dave Varner	Water Superintendent, B.T., MO	(314) 358-2254
Jeff J. Weatherly	CDM Federal	(913) 492-8181

SUMMARY:

No surface water intakes, Blended system-three wells. Wells #1,2 are drawing from an abandoned mine shaft at 730 feet, combined capacity of 615 GPM. Well No. 3 is drilled to 750 feet. Capacity of 310 GPM. Water system only serves those in Bonne Terre, East Bonne Terre is on private wells. Well log for Well No. 3 is: 0-25' clay rock, 25-30' hard limestone, 30-103' Gray Limestone, 103-113' broken limestone with shales, 113-329' Hard dark brown dolomite, 329-336' Broken limestone, 336-489' gray limestone with chert, 489-519' soft green/black rock, 519-539' gray limestone, 539-750' sandstone and granites. Source: Dept. of Revenue, State of Missouri, letter dated 5/24/88.-END OF CONVERSATION-

DISTRIBUTION: [ ] PARTICIPANTS [X] FILE INFORMATION ACTION

OTHER: Well lithology included

Blended system 3 wells

All others private wells.

Jeff Wea

1/30/92

File No.: 008

CDM Federal Programs Corporation

RECORD OF COMMUNICATION

[X] TELEPHONE CONVERSATION

[ ] INCOMING [X] OUTGOING

[ ] MEETING

DATE: January 28, 1993

TIME: 1723:00 hrs

RECORDED BY: Jeff J. Weatherly

PROJECT: Bonne Terre Mine (SACM)

CONTRACT NO.: 7760-013-SM2-BTMT

SUBJECT: Well information

PARTICIPANTS	ORGANIZATION/DEPARTMENT	TELEPHONE NO./EXT.
Nelma Russell	Office MGR, Goggins Well Drilling	(314) 431-2450
Jeff J. Weatherly	CDM Federal	(913) 492-8181

SUMMARY:

Called for private well information. Unknown as to how many private wells in the area but there are a lot of them, many are old. Estimated in the hundreds for a 4-mile radius. All folks outside a city system are on private wells. Average depth of private wells drilled by Goggins is between 300-400 feet.. -END OF CONVERSATION-

DISTRIBUTION: [ ] PARTICIPANTS [X] FILE

OTHER:	INFORMATION	ACTION
300-400' AVERAGE DEPTH OF PRIVATE WELLS	[ ]	[ ]
100'S OF PRIVATE WELLS	[ ]	[ ]
RURAL RESIDENTS ARE ON PRIVATE WELLS	[ ]	[ ]
	[ ]	[ ]

1/30/92

File No.: 009

JJW

CDM Federal Programs Corporation

RECORD OF COMMUNICATION

[X] TELEPHONE CONVERSATION — DATE: January 29, 1993

[ ] INCOMING [X] OUTGOING — TIME: 1327:00 hrs

[ ] MEETING — RECORDED BY: Jeff J. Weatherly

PROJECT: Bonne Terre Mine (SACM) — CONTRACT NO.: 7760-013-SM2-BTMT

SUBJECT: Flow rate information

PARTICIPANTS	ORGANIZATION/DEPARTMENT	TELEPHONE NO./EXT.
Gil Malone	USGS-Rolla, MO (Leon Reed)	(314)341-0843
Jeff J. Weatherly	CDM Federal	(913) 492-8181

SUMMARY:

Called for Leon Reed, spoke to Gil Malone. Annual average discharge for Big River is 187 cfs measured at Irondale. 692 cfs measured at Richwood. No flow rate information recorded for Turkey Creek near Bonne Terre, MO.-END OF CONVERSATION-

DISTRIBUTION: [ ] PARTICIPANTS [X] FILE — INFORMATION — ACTION

OTHER: 187 AT IRONDALE, BIG RIVER

692 AT RICHWOOD, BIG RIVER

NO FLOW INFORMATION FOR TURKEY CREEK

Jeff Weatherly

1/30/92

File No.: 010

CDM Federal Programs Corporation

RECORD OF COMMUNICATION

[X] TELEPHONE CONVERSATION

DATE: January 31, 1993

[ ] INCOMING [ ] OUTGOING

TIME: 1520:00 hrs

[ ] MEETING

RECORDED BY: Jeff J. Weatherly

PROJECT: Bonne Terre Mine (SACM)

CONTRACT NO.: 7760-013-SM2-BTMT

SUBJECT: BONNE TERRE MINE INFORMATION

PARTICIPANTS	ORGANIZATION/DEPARTMENT	TELEPHONE NO./EXT.
Debbie Loewe	Tour MGR, Bonne Terre Mine	(314) 358-5000
Jeff J. Weatherly	CDM Federal	(913) 492-8181

SUMMARY:

There are 85,000 walking and boating tours annually, There are about 15,000 scuba dives annually. Tours started in 1968 walking, 1990 boating, 1980 for diving. Mine is leased from St. Joe Minerals Corp. by West End Diving out of St. Louis, Owner of West End is Doug Goergens. The mine has two pumps that keep the water level at dock level in the mine. The pumps have a capacity to pump 1 million gallons in a 24 hour period. Mine draw-down in a 7 day period is 4-5 inches running the pumps 24 hrs. No permit to discharge the water into Turkey Creek. James Petts, former geologist for St. Joe Minerals calculated the mine to hold 2 billion gallons of water if full. Water purged from the mine goes to Turkey creek as well as the storm sewer system for Bonne Terre. James Petts may be contacted via Carol Georing at (314) 431-1550. Earl Fairclothe is another good person to talk to he is at the tour office (314) 358-2148.-END OF CONVERSATION-

DISTRIBUTION: [ ] PARTICIPANTS [X] FILE

OTHER:	INFORMATION	ACTION
BACKGROUND INFORMATION	[ ]	[ ]
CONTACT JAMES PETTS (314)431-1550	[ ]	[ ]
CONTACT EARL FAIRCLOTHE (314) 358-2148	[ ]	[ ]
	[ ]	[ ]

1/30/92

File No.: 011

CDM Federal Programs Corporation

RECORD OF COMMUNICATION

[X] TELEPHONE CONVERSATION DATE: January 31, 1993

[ ] INCOMING [X] OUTGOING TIME: 1535:00 hrs

[ ] MEETING RECORDED BY: Jeff J. Weatherly

PROJECT: Bonne Terre Mine (SACM) CONTRACT NO.: 7760-013-SM2-BTMT`

SUBJECT: BONNE TERRE MINE INFORMATION

PARTICIPANTS	ORGANIZATION/DEPARTMENT	TELEPHONE NO./EXT.
Earl Fairclothe	Former Mine Employee	(314) 358-2148
Jeff J. Weatherly	CDM Federal	(913) 492-8181

SUMMARY:

Worked at the mine for 45 years until its closure in 1961. Mr. Fairclothe worked in the personnel office. There were 200 personnel during the later years, the most that worked in the mine was 800 in 1907 when the foundry needed 400 persons to run it. The lead content in the ore was 5-6% in the earlier days, then dropped off to <2% near closure (averages). The ore averaged: 13% sulfur, 5-6% lead, <1% nickel, 0.08% silver. James Pettus would have more information on mine production. He might be able to be reached at PC Land (314) 431-2056.-END OF CONVERSATION-

DISTRIBUTION: [ ] PARTICIPANTS [X] FILE INFORMATION ACTION

OTHER: 5-6% lead

200 last days, 800 max. employees

Contact James Pettus for more production information.

Jeff Weatherly

1/30/92 File No.: 012

JW

CDM Federal Programs Corporation

RECORD OF COMMUNICATION

[X] TELEPHONE CONVERSATION

[ ] INCOMING [X] OUTGOING

[ ] MEETING

DATE: February 1, 1993

TIME: 925:00 hrs

RECORDED BY: Jeff J. Weatherly

PROJECT: Bonne Terre Mine (SACM)

CONTRACT NO.: 7760-013-SM2-BTMT

SUBJECT: Private Well Information

PARTICIPANTS	ORGANIZATION/DEPARTMENT	TELEPHONE NO./EXT.
Joyce Tilley	Sec/Tres of Terre du Lac Utilities	(314) 358-3376
Jeff J. Weatherly	CDM Federal	(913) 492-8181

SUMMARY:

Served by a municipal well system. 3 wells that are blended. not production information or finished depth available at the time of call. Well location: 2 wells are in plat No. 4 and 1 is in plat No. 1. No township and range information. All wells are at least 8 miles from Bonne Terre, Missouri. Terre du Lac is a Lake development. those on the outside of the development are on private wells. Well system serves 910 customers.-END OF CONVERSATION-

DISTRIBUTION: [ ] PARTICIPANTS [X] FILE INFORMATION ACTION

OTHER: OUTSIDE THE 4-MILE RADIUS

BLENDED SYSTEM 3 WELLS - NO INFO.

PRIVATE WELLS OUTSIDE THE LAKE DEVELOPMENT.

Jeff Weatherly

1/30/92

File No.: 013

JW

CDM Federal Programs Corporation

RECORD OF COMMUNICATION

[X] TELEPHONE CONVERSATION [ ] INCOMING [X] OUTGOING

[ ] MEETING

DATE: February 1, 1993

TIME: 1004:00 hrs

RECORDED BY: Jeff J. Weatherly

PROJECT: Bonne Terre Mine (SACM)

CONTRACT NO.: 7760-013-SM2-BTMT`

SUBJECT: Private Well Information

PARTICIPANTS	ORGANIZATION/DEPARTMENT	TELEPHONE NO./EXT.
BOB ROBBINS	Lake Timberline Resident	(314) 358-8852
Jeff J. Weatherly	CDM Federal	(913) 492-8181

SUMMARY:

Called to see if Lake Timberline has a municipal water system. All houses in that area are on private wells. It is a lake development..-END OF CONVERSATION-

DISTRIBUTION: [ ] PARTICIPANTS [X] FILE INFORMATION ACTION

OTHER: Lake Timberline area is on private wells

Jeff Weat

1/30/92

File No.: 014

The Stratigraphic Succession in Missouri

Coordinated by
WALLACE B. HOWE

Edited by
JOHN W. KOENIG

Vol. XL, Second Series

September 1961

STATE OF MISSOURI
Department of Business and Administration

Division of
GEOLOGICAL SURVEY AND WATER RESOURCES
THOMAS R. BEVERIDGE, *State Geologist*
Rolla, Missouri

the Paleozoic Systems up to and including the Pennsylvanian. In the southeastern part of the state, in the lowland area, the rock succession is thicker but most of the Paleozoic Systems are missing. As much as 4,700 feet of post-Precambrian rock has been penetrated by one of the deepest wells in the area, but only the deepest part of this well is in Paleozoic rock of Cambrian age. The balance of the succession is composed of Cretaceous and Teritary rocks.

The structural attitude of the Paleozoic rocks throughout the state is controlled principally by the shape of the Ozark uplift, the apex of which forms the core of the St. Francois Mountains. Paleozoic strata dip away in all directions from the periphery of the St. Francois Mountains into surrounding structural basins: the Forest City basin to the northwest, the Illinois basin to the northeast, the Anadarko basin to the southwest, the Arkoma basin to the south, and the depression of the Mississippi Embayment to the southeast. Some of the more prominent secondary structural features which locally affect the attitude of Paleozoic strata within the state are the Lincoln fold in northeastern Missouri, the Mineola arch in central Missouri, the Cap au Gres fault north of St. Louis, the Little Saline fault complex in Ste. Genevieve County, and the Chesapeake fault zone southwest of Springfield.

Cambrian System

by

William C. Hayes and Robert D. Knight

Upper Cambrian Series

All the Cambrian strata in Missouri are regarded as Late Cambrian in age. The unconformity at the base of the Series is particularly striking in the St. Francois Mountain area where prominent ridges and knobs of Precambrian granite and felsite are in contact with Cambrian strata. The lower part of the Series consists of a quartzose sandstone, the upper part of dolomite and shale. Exposures of the sandstone are generally limited to the St. Francois Mountain area where they onlap the flanks of Precambrian knobs. Outcrops of successively higher units occur in peripheral, annular patterns around the area. Away from the uplift, Upper Cambrian formations dip beneath younger Paleozoic strata and are present in the subsurface throughout the state except in those areas where they have overlapped Precambrian topographic highs and have been subsequently removed by erosion.

The combined thicknesses of the strata which form the Upper Cambrian Series in Missouri total approximately 2,000 feet. The Series contains six formations, two of which form a group. In order of decreasing age, they are as follows: the Lamotte, Bonneterre, Davis, Derby-Doerun, Potosi, and Eminence formations; the Davis and Derby-Doerun together form the Elvins group.

Lamotte formation.—The Lamotte is predominantly a quartzose sandstone that in many places grades laterally into arkose and conglomerate. Pebbles and boulders of felsite are the chief constituents of the conglomerates which immediately overlie Precambrian rocks in many places. The color of the sandstone ranges from light gray or white to yellow, brown, or red. Red to purple silty shale is locally present, and lenses of arenaceous dolomite are scattered through the upper part of the formation.

The Lamotte attains its maximum thickness of about 500 feet in the depressions between Precambrian ridges and knobs. Where the formation onlaps these knobs and hills, it pinches out and is overlapped by younger formations.

Exposures of Lamotte are in general restricted to the St. Francois Mountain area in Madison, Ste. Genevieve, Iron, and southeastern Washington Counties. The Lamotte appears to be absent in west-central Madison County. The formation is persistent in the subsurface throughout Missouri except on Precambrian highs where younger formations overlap it. Regional variations in thickness of the Lamotte within the state are indicated by the following data: In Howell County the formation is approximately 200 feet thick, in Laclede County it is 300 feet thick, in Barry County, 125 feet, and in Ralls County, 340 feet. In Nemaha County, Nebraska, across the Missouri River from Atchison County in northwestern Missouri, it is 65 feet thick.

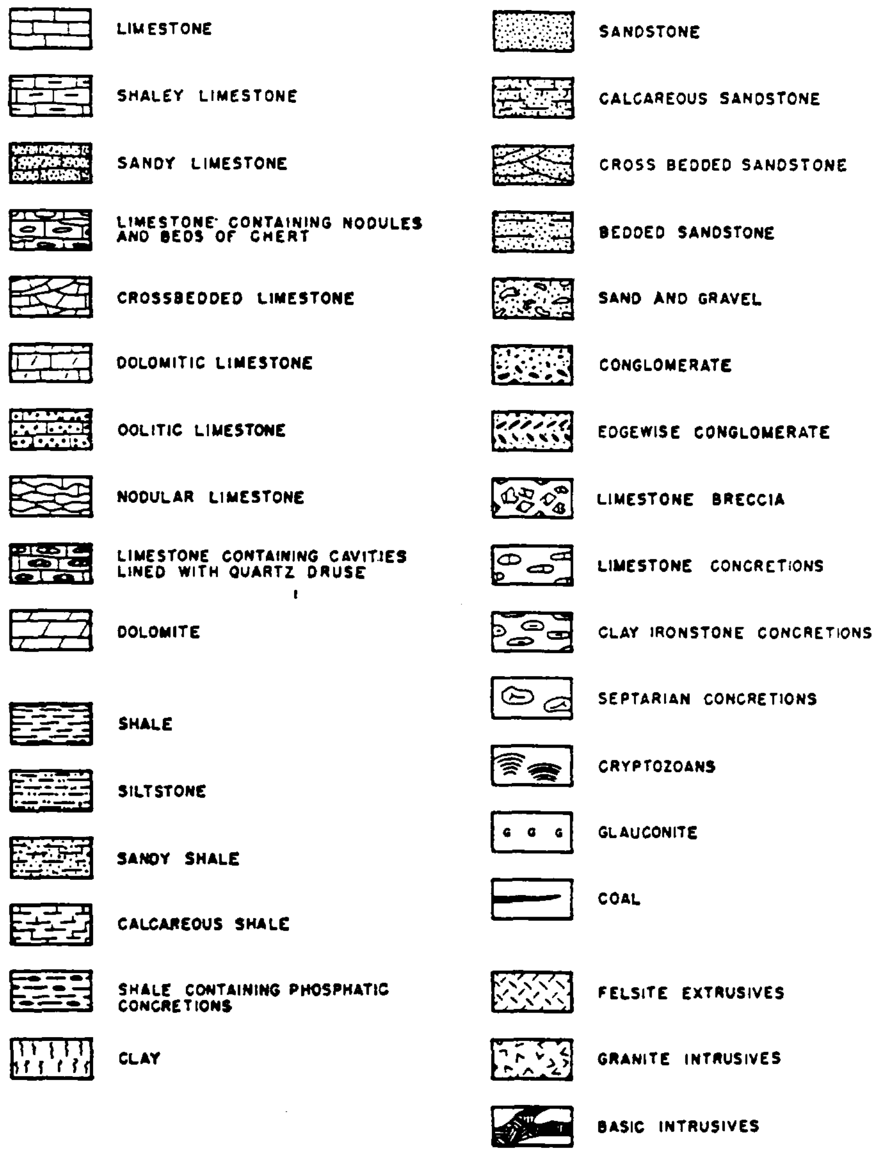
The Lamotte is quarried for dimension stone in the St. Francois Mountain area.

Bonneterre formation.—The Bonneterre is typically a light gray, medium- to fine-grained, medium-bedded dolomite but consists of relatively pure limestone in some areas. In places, it is very coarse grained, and it contains small cavities which are lined with dolomite rhombs. Locally, parts of the Bonneterre are glauconitic and shaly with the shale occurring in beds less than 2 inches thick. In some areas, the formation contains beds of relatively pure, thin-bedded, pink limestone which is referred to as "Taum Sauk marble".

In the Fredericktown area, the formation has been divided into six units on the basis of insoluble residues. In the Lead Belt, eight principal units are recognized, although all are not identifiable at any one locality. Because of the importance of the formation as a host rock to the ore deposits of the Lead Belt, the Bonneterre has been studied in more detail there than elsewhere. Structures that are important as ore controls are: clastic carbonate bars or ridges, algal structures, and masses of submarine breccia. Major lead production to date has been from the lower half of the formation. Wherever the Bonneterre has been deposited near or directly on the Precambrian surface, it contains pebbles and cobbles of igneous rock much of which is felsite. The host rock at the St. Joseph Lead Company's Hayden Creek mine is a granite conglomerate cemented by dolomite. The ore is present in the dolomite and fills fractures in the granite boulders.

The relationship of the Bonneterre and the underlying Lamotte is one of conformity. The lower part of the Bonneterre consists of alternating beds of dolomite and arenaceous dolomite with the amount

LEGEND


LIMESTONE
SHALEY LIMESTONE
SANDY LIMESTONE
LIMESTONE CONTAINING NODULES AND BEDS OF CHERT
CROSSBEDDED LIMESTONE
DOLOMITIC LIMESTONE
OOLITIC LIMESTONE
NODULAR LIMESTONE
LIMESTONE CONTAINING CAVITIES LINED WITH QUARTZ DRUSE
DOLOMITE
SHALE
SILTSTONE
SANDY SHALE
CALCAREOUS SHALE
SHALE CONTAINING PHOSPHATIC CONCRETIONS
CLAY
SANDSTONE
CALCAREOUS SANDSTONE
CROSS BEDDED SANDSTONE
BEDDED SANDSTONE
SAND AND GRAVEL
CONGLOMERATE
EDGEWISE CONGLOMERATE
LIMESTONE BRECCIA
LIMESTONE CONCRETIONS
CLAY IRONSTONE CONCRETIONS
SEPTARIAN CONCRETIONS
CRYPTOZOANS
GLAUCONITE
COAL
FELSITE EXTRUSIVES
GRANITE INTRUSIVES
BASIC INTRUSIVES

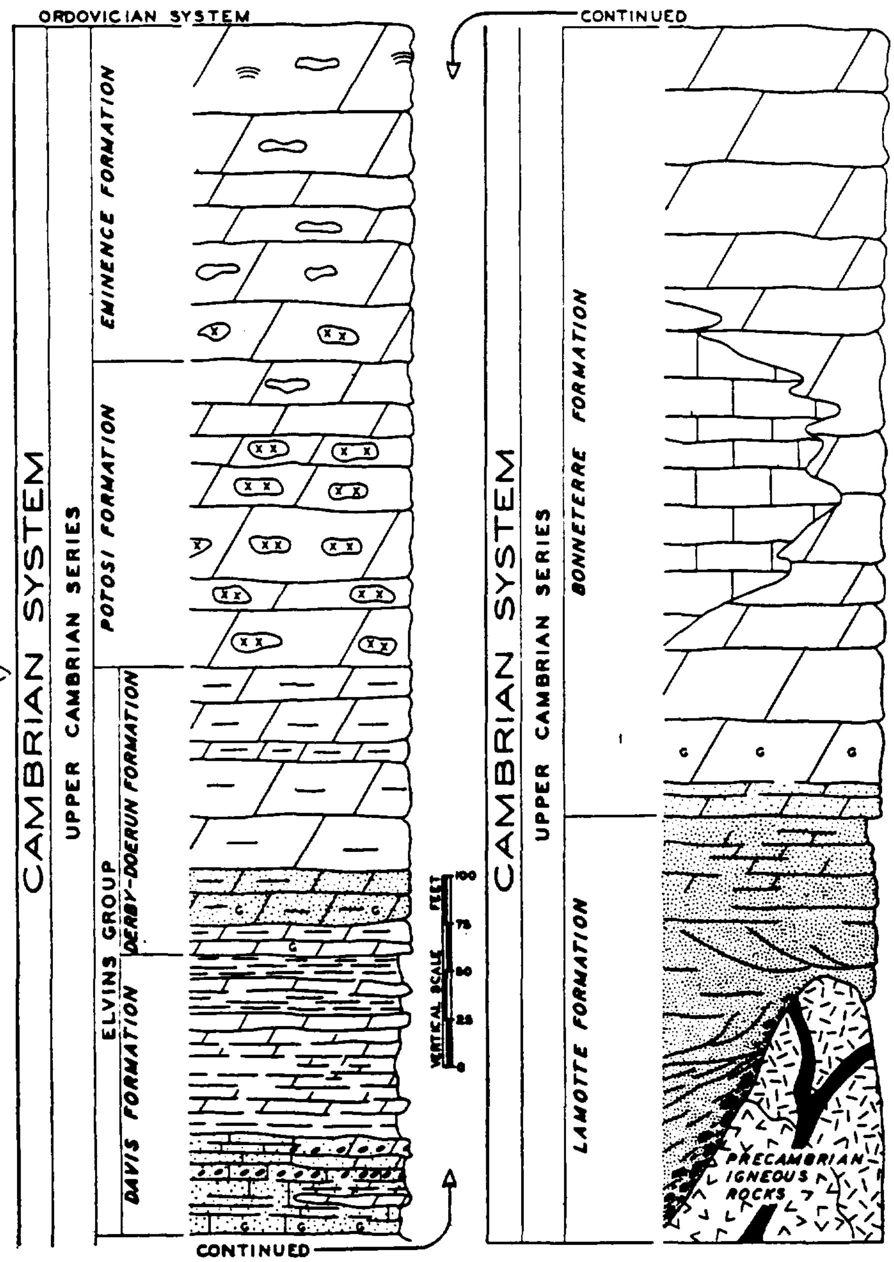


Fig. 3. Cambrian System; Upper Cambrian Series.

of sand increasing toward the base. This sandy zone is usually 10 to 20 feet thick but may approach a thickness of 200 feet. The Bonneterre overlaps the underlying Lamotte on the flanks of Precambrian highs.

Most of the Bonneterre exposures lie to the north and east of the main area of Precambrian exposures, and the formation is concealed by younger beds to the west and south. It occurs in the subsurface throughout most of the state and attains a maximum known thickness of 1,580 feet in the subsurface in Pemiscot County. In the Lead Belt, the formation has an approximate thickness of from 375 to 400 feet.

ELVINS GROUP.—The Elvins group, which consists of the Davis and Derby-Doerun formations, is a readily recognizable unit anywhere in the state. The lower part is shaly in the Lead Belt area but becomes predominantly dolomitic to the south. The upper part of the Elvins consists of fine-grained, thin- to medium-bedded, shaly dolomite.

Davis formation.—The Davis is the lower of the two formations which make up the Elvins group. The formation is conformable with the underlying Bonneterre and contains shale, siltstone, fine-grained sandstone, dolomite, and limestone conglomerate; shale is more prevalent in the Lead Belt than elsewhere. Much of the siltstone and fine-grained sandstone is glauconitic and has a "salt and pepper" appearance.

An important marker in the Davis is the *Eoorthis* brachiopod zone which is usually confined to a bed 1 or 2 feet thick that lies 30 or 35 feet below the top of the formation.

"Flat-pebble" and edgewise conglomerates are characteristic of the Davis. The "flat-pebble" conglomerates consist of rounded disclike pebbles of fine-grained limestone that are embedded in a medium-grained limestone matrix. The pebbles lie with their flat surfaces more or less parallel to the bedding planes. In the imbricate or edgewise conglomerates, the discs or lenses of fine-grained limestone are generally arranged with their longer axes perpendicular to or steeply inclined to the bedding planes. In some places, a group of edgewise pebbles will form a radiating or fanlike pattern.

Rounded, boulder size masses of light-colored, fine-grained, mottled limestone are present about 60 feet below the top of the Davis in the Lead Belt area. This horizon is informally referred to as the "Marble boulder bed".

The formation averages 170 feet in thickness. Its maximum recorded thickness is 225 feet. It thins to a featheredge wherever it onlaps Precambrian knobs.

Derby-Doerun formation.—The Derby and the overlying Doe Run formation were originally defined in 1908 from exposures in the vicinity of mines operated by the Derby Lead Company and the Doe Run Lead Company in the Lead Belt area at that time. However, the conformable relationship and similar lithology of the two units has since led most stratigraphers to consider them as a single unit, and the combination of the two names, Derby and Doe Run, is now accepted as the formation name; Derby-Doerun.

In its outcrop area in southeast Missouri, the Derby-Doerun consists of thin- to medium-bedded dolomite which alternates with thin-bedded siltstone and shale. The dolomite beds are medium to fine grained, buff to brown, argillaceous, and silty. The chert content of the formation is very low, amounting to less than 10 percent of the rock by volume. Glauconite is present in the lower 40 to 50 feet of the formation. About 50 feet below the top of the formation, hexactinellid and other types of sponge spicules are common, and echinoderm ossicles are frequently present.

The contact of the Derby-Doerun and the underlying Davis is conformable, and in many places where it is not exposed, its position may be inferred with considerable accuracy by reference to the *Eoorthis* zone in the Davis formation. The thickness of the Derby-Doerun is approximately 150 feet; however, its range in thickness is from 0 to 200 feet.

Potosi formation.—The Potosi is a massive, thickly bedded, medium to fine-grained dolomite which characteristically contains an abundance of quartz druse or so-called "mineral blossom" that is associated with chert. Druse-free chert is uncommon. The rock is typically brownish gray in color and weathers to a light gray. A notable characteristic of the Potosi, as well as of a few other lower Paleozoic formations, is that the freshly broken rock gives off a pronounced bituminous odor. Deep red, sticky, residual clay is a surface indication of the presence of the Potosi in its outcrop area. The relationship of the Potosi and the underlying Derby-Doerun is one of conformity.

The Potosi outcrop area encircles the St. Francois Mountains and includes a considerable part of southern Washington County where barite is present in commercial quantity. The barite occurs in the residual clay and druse mantle of the weathered formation as well as in the formation. The Potosi is present in the subsurface throughout most of the state, but at widely scattered localities, it is thin or absent.

The thickness of the Potosi in its outcrop area ranges from about 75 feet to a maximum of 300 feet. Its average thickness is 200 feet. Deep well records from southwestern and northern Missouri show that the Potosi thins laterally from its outcrop area. Well records at Springfield show that the Potosi in that area is less than 30 feet thick. In northern Missouri, its thickness ranges from 0 to 75 feet.

Eminence formation.—The Eminence formation is composed principally of medium to massively bedded, light gray, medium- to coarse-grained dolomite. It contains a small amount of chert in the form of small nodules and angular fragments that is present mostly in the upper half of the formation. The small amount of quartz druse which is found in the formation is similar to the druse in the underlying Potosi. In some areas, the Eminence formation contains large massive chert boulders and blocks as much as 6 feet in diameter. White oolitic chert is locally present in the upper part of the formation. Molds and

SOIL SURVEY OF

ST. FRANCOIS COUNTY, MISSOURI

United States Department of Agriculture
Soil Conservation Service and
Forest Service
In Cooperation with
Missouri Agricultural Experiment Station

August 1981

Soil survey of
St. Francois County, Missouri

By Burton L. Brown, Soil Conservation Service

Fieldwork by Burton L. Brown, Party leader, and
James D. Childress and Dennis K. Potter, Soil Conservation Service, and
John D. Preston and Daniel P. Wilcox,
St. Francois County Soil and Water Conservation District

United States Department of Agriculture
Soil Conservation Service and Forest Service
in cooperation with
Missouri Agricultural Experiment Station

St. Francois County is in the east-central part of Missouri, on the eastern fringe of the Ozark region. In area the county is 292,480 acres, or about 457 square miles. It is shaped roughly like a triangle. Its western border is about 29 miles long and its southern border is 29 miles wide. St. Francois County is bordered on the north by Jefferson County, on the east by Ste. Genevieve County, on the south by Madison County, on the southwest by Iron County, and on the northwest by Washington County. Farmington is the county seat. In 1970, the population of the county was 36,875.

Surface features of the county are mainly determined by differences in geological structures surrounding the Ozark Dome. About 20 percent of the county is made up of the St. Francois Mountains, where soils formed in residuum of igneous rocks. Another 52 percent of the county is on the Farmington Plain, where the soils are underlain by sandstone and dolomite. The remaining 28 percent of the area is on the old surface and the dissected topography of the Salem Plateau, where the major soil material is red cherty clay.

The highest elevation is 1,650 feet, on Brown Mountain near the southwest corner of the county. The main watershed divide runs from northeast to southwest through the middle of the county. The Big River flows through the northern part of the county in a general northerly course and the St. Francis River flows across the lower part of the county in a southerly direction. The lowest elevation in the county is approximately 565 feet, where Big River leaves the county in the northwest corner.

general nature of the survey area

In this section, climate, history and development, and physiography and geology are discussed.

climate

St. Francois County is hot in summer, especially at lo[w] elevations, and moderately cool in winter, especially on mountains and high hills. Rainfall is fairly heavy and wel[l] distributed throughout the year. Snow falls nearly every winter, but snow cover lasts only a few days at a time.

Table 1 gives data on temperature and precipitation for the survey area as recorded at Farmington, Missour[i] in the period 1951 to 1974. Table 2 shows probable dates of the first freeze in fall and the last freeze in spring. Table 3 provides data on length of the growing season.

In winter the average temperature is 35 degrees F, and the average daily minimum temperature is 24 degrees. The lowest temperature on record, which occurred at Farmington on January 14, 1964, is -20 degrees. In summer the average temperature is 75 degrees, and the average daily maximum temperature is 88 degrees. The highest recorded temperature, which occurred on July 14, 1954, is 108 degrees.

Growing degree days are shown in table 1. They are equivalent to "heat units." During the month, growing degree days accumulate by the amount that the average temperature each day exceeds a base temperature (50 degrees F). The normal monthly accumulation is used to schedule single or successive plantings of a crop between the last freeze in spring and the first freeze in fall.

Of the total annual precipitation, 23 inches, or 60 percent, usually falls in April through September, which includes the growing season for most crops. In 2 years out of 10, the rainfall in April through September is less than 18 inches. The heaviest 1-day rainfall during the period of record was 4.95 inches at Farmington on June 30, 1957. Thunderstorms occur on about 50 days each year, and most occur in summer.

Average seasonal snowfall is 12 inches. The greatest snow depth at any one time during the period of record was 17 inches. On an average, 5 days have at least 1 inch of snow on the ground, but the number of such days varies greatly from year to year.

The average relative humidity in midafternoon is about 60 percent. Humidity is higher at night, and the average at dawn is about 80 percent. The sun shines 70 percent of the time possible in summer and 50 percent in winter. The prevailing wind is from the south. Average windspeed is highest, 12 miles per hour, in March.

history and development

Early inhabitants of St. Francois County were agricultural village dwellers of the Mississippian culture (*15*). Small mounds along the valleys of the Big River and the St. Francis River are mute reminders of these people. Later, the Osage Indians roamed this area of the state. European settlement began in the late 1700's.

St. Francois County was first under French dominance as part of the Louisiana Territory, a French holding. France sold the territory to the United States as a part of the Louisiana Purchase in 1803.

The first communities, Murphy Settlement, Cook Settlement, and Alley's Mines, were established prior to 1803. These communities were mainly agricultural. Murphy Settlement, later named Farmington, was started about 1800 when William Murphy, a Baptist minister from Tennessee, built a log cabin. He chose the deep red (Crider) soils on the rolling Farmington Plain where a magnificent forest testified to the productivity of the soils. Cook settlement, near the present community of Libertyville, grew up in a similar manner. The area was chosen by Nathaniel Cook who came from Scott County, Kentucky in about 1797. Alley's Mines was located on or near Big River. It was named for Thomas Alley, who discovered and developed the lead mine there.

St. Francois became a county in 1821, the same year Missouri gained statehood. St. Francois was formed from parts of three other counties already established—Jefferson, Ste. Genevieve, and Washington.

Mining played an important part in the development of the county. Towns such as Bonne Terre, Flat River, Desloge, and Iron Mountain were established in rich mining areas. All of these with the exception of Iron Mountain were the sites of very rich lead deposits. Bonne Terre, meaning "good earth," was the name given to the area's lead-containing clay by the miners. Iron Mountain was first believed to be a mountain of pure iron by the Spanish. Presently there are no active lead or iron mines in the county.

The "Old Plank Road," running from Ste. Genevieve to Iron Mountain, was the first improved road in Missouri (*11*). This road was built of heavy timbers laid down lengthwise on which 8-foot oak planks were nailed crosswise. Wagons containing iron from Iron Mountain and Pilot Knob were pulled by oxen, horses, and mules east to the river and on the return trip brought back freight and supplies. Repairs of the Old Plank Road ceased about 1857, the year the St. Louis and Iron Mountain Railroad was built.

Most of the early settlers came in search of productive soils to farm (fig. 1). Their first task was to clear the land for cultivation. Trees were cut, burned, split into rails, or used to construct log houses and barns. Fields were planted to corn, cotton, tobacco, and garden vegetables. Livestock required little attention. Horses, cattle, mules, and hogs were turned out on open range to graze. Open grazing continued until about 1920.

Farming expanded throughout the rolling plain between Farmington and Libertyville and to the creeks and river valleys beyond. By 1978, about 50 percent of the county had been cleared and was being used for pasture, hay, and corn.

Despite a decline in cropland acreage, yields of most crops have steadily increased. About 19,200 acres of corn was harvested in St. Francois County in 1932 (*6*). Two years later, in 1934, the amount of land in corn declined to 8,800 acres, and it dropped to 1,700 acres in 1964. In 1977, this figure rose to 2,600 acres. The yield of corn, on the other hand, averaged 20.5 bushels per acre in 1928, 40 bushels per acre in 1946, and 85.2 bushels per acre in 1975.

The acreage of land in wheat has also declined rather steadily, from 16,900 acres in 1919 to 900 acres in 1977. Yields of wheat have risen more slowly than corn yields, from 14.5 bushels per acre in 1928 to 14.9 bushels per acre in 1946 and 34.3 bushels per acre in 1975.

Oats, a major crop of 93,200 acres in 1928, has dropped during the last 20 years to only a few hundred acres per year. Soybeans, introduced in the early 1940's, has continued to be a very minor crop, with only a few hundred acres grown each year. Hay acreages and yields have remained rather consistent for the past 60 years. In 1977, 27,500 acres of hay yielding an average of 1.4 tons per acre was grown.

The number of cattle in St. Francois County increased from 13,000 head in 1920 to 28,400 head in 1978. The number of hogs has fluctuated rather drastically in the past 60 years, from a high of 14,900 in 1944 to a low of 5,500 in 1966. Sheep numbers have declined from 3,300 head in 1938 to fewer than 100 today.

The population of the county is presently at an all time high of about 39,000. In 1830, the county had 2,366 people and by 1940 the number had grown to 35,950. The number of people in agricultural occupations has declined. In 1918, over 80 percent of the population was engaged in mining and most of the remainder was employed in agriculture. In 1966, out of a total work force of 10,380, only 420 people (4 percent) worked directly in agriculture and most of the rest worked in mining. Current trends are toward decreases in the number of farms, the acreage in farms, and the number of people actively engaged in farming.

physiography and geology

St. Francois County lies on the eastern side of the Ozark Highland (*4*). It has a variety of surface features. Major physical features are the St. Francois Mountains, the Farmington Plain, and the dissected topography of the Salem Plateau (fig. 2).

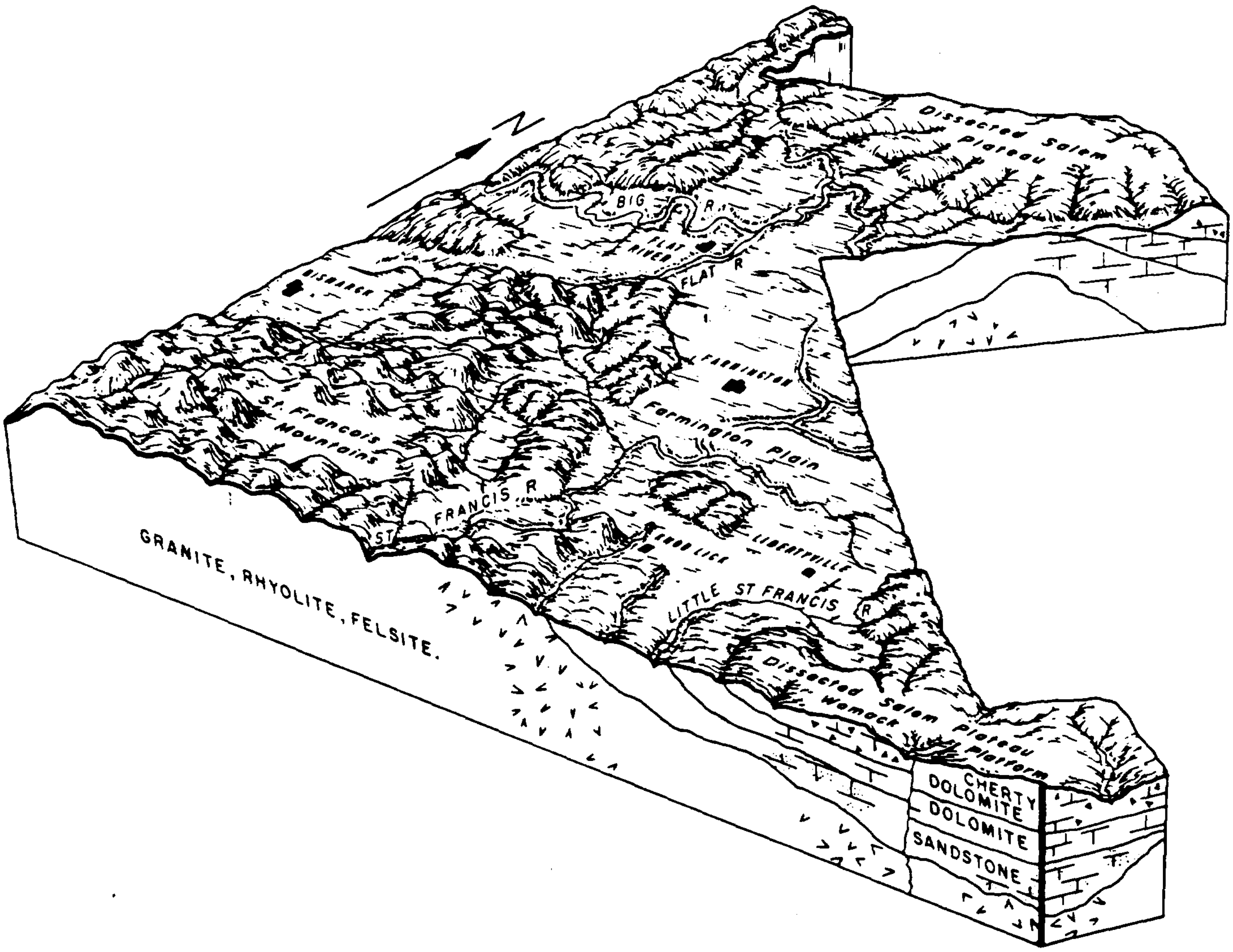


Figure 2.—Physiography, relief, and drainage of St. Francois County.

The St. Francois Mountains are a closely assembled group of peaks that rise islandlike above the surrounding area. Granites, rhyolites, and felsites are the principal rocks. The major peaks are made up of felsitic rocks or rhyolitic lava flows that apparently were ejected from volcanic vents and cracks in the earth's crust. These structures are thought to be essentially unaltered from their original form except for stream-cut narrows, talus slopes, and beach accumulations (*7*). The granites are on land surfaces that geologists consider to be denuded magmas responsible for large-scale crustal movements which caused the general faulting, folding, and tilting of the area. No evidence of the former overburden remains in areas of the intrusive rocks, indicating that extensive truncation has taken place. Such massive removal would seem to have required more than the normal erosion cycle, perhaps tsunamis. Irondale and Knobtop soils formed in thin residuum of rhyolitic and associated extrusives, and Syenite and Delassus soils are on the landscapes of granite and associated intrusives. The intermountain valleys are accidents. They have no relationship to present erosion cycles.

Below the mountains is a region of dissected topography deeply cut into the cherty red clay sediments of the upper Cambrian and the lower Paleozoic. This landscape is represented by the uplands that frame the north part of the county and the southeast corner and that are traceable across the county by numerous hills and monadnocks. The high ridges to the north and the summit of the Womack platform range in altitude from 1,100 to 1,200 feet. This plateau is also traceable through the St. Francois Mountains at the same altitude. Small platforms lie at the base of Stono, Buck, Brown, and Knob Lick Mountains. Loughboro soils are on the most stable parts of these platforms. The exposed magmas of Washita Mountaintop and the Flatwoods are of this same general elevation.

The Salem Plateau may well be a structural plain controlled by a former sea level. This base level, including the exposed magmas, may be the effect of marine denudation, especially by tsunamis. The immense erosive power of such forces is well documented (*21*). Not only could the tsunami theory explain the complete removal of the sedimentary overburden, but it could also explain the comparative absence of stones and boulders on the summits and their accumulation on the adjacent valley sides and ravines. Rounded stones and boulders cover as much as 50 percent of the surface of Syenite soils (fig. 3). The ruggedly incised Salem Plateau has steep side slopes of Goss soils. The more stable slopes, ridges, and divides are occupied by Hildebrecht, Lebanon, and Wilderness soils, all having well formed fragipans.

A still lower plain is much in evidence in St. Francois County—the Farmington Plain (also called the Jonca Plain). Except for the deep entrenchments of Big River and its tributaries, the Farmington Plain has a gently rolling to rolling surface. Its altitude is 900 to 1,000 feet. This structure is underlain by the Lamotte sandstone and the Bonneterre dolomite. Sandstone has been exposed as a result of tilting, folding, and subsequent erosion.

The Farmington Plain is difficult to explain in terms of a normal erosion cycle. It forms a major divide between the north-flowing Big River and the south-flowing St. Francis River. There is no evidence that it was formed by a through-flowing stream or by headward erosion. It appears more likely that this plain was a second major sea level position. The plain was truncated by wave action and the irregular pinnacled surface of the bedrock was sculpted by running water and afterward covered with clayey sediment. Contact between the soil and the dolomite bedrock is one of unconformity. Caneyville, Crider, and Fourche soils formed in clayey material over dolomite. Jonca, Lamotte, and Ramsey soils formed in loamy material over sandstone.

Later and more temporary base levels are evidenced by upland benches below the Farmington Plain and stream terraces along the major streams. Ashton and Auxvasse soils occupy these positions.

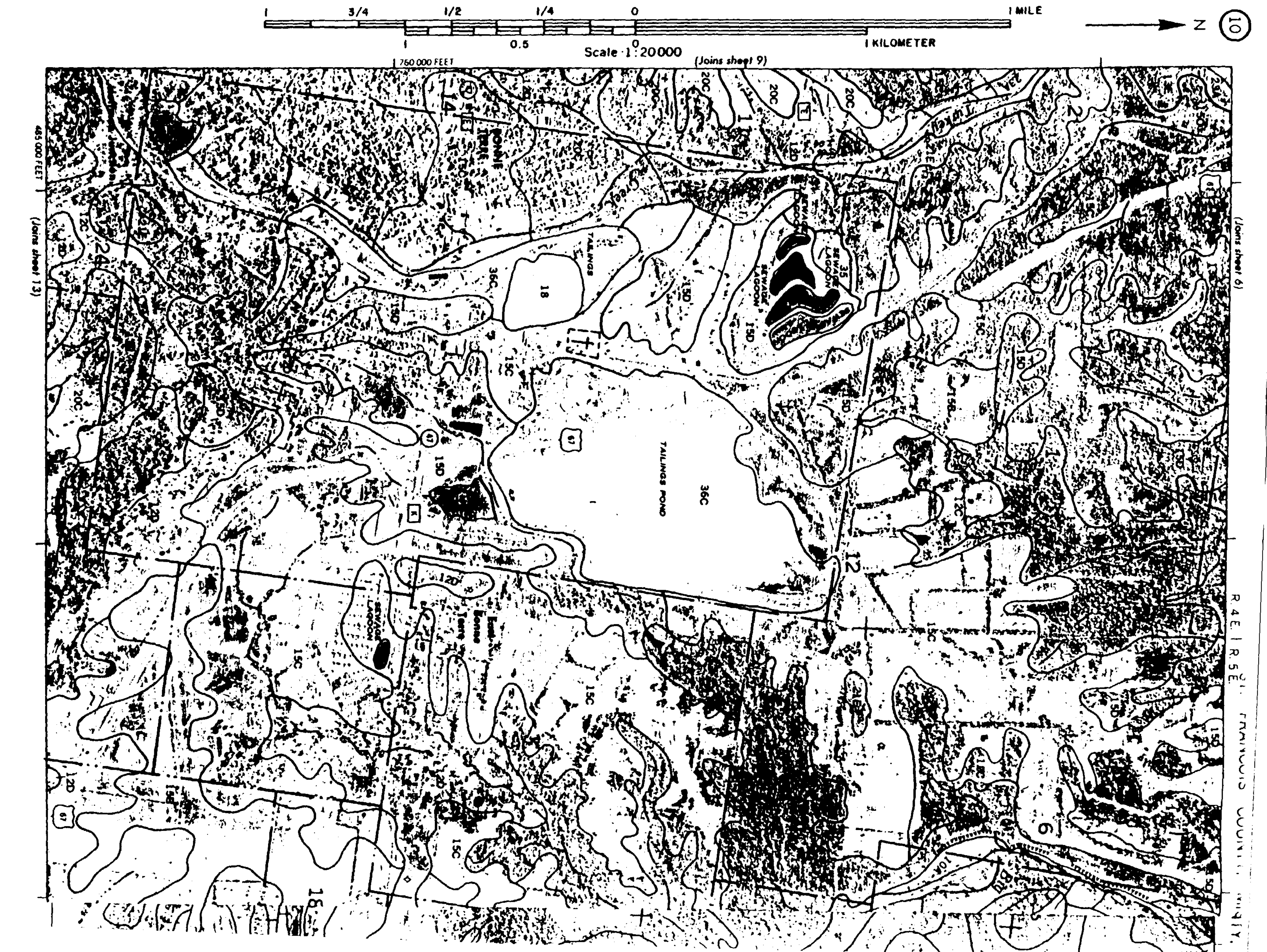
The drainage pattern of the county seems to have been fixed early in the geomorphic history of the county Structural features of more recent origin have not changed the general direction of flow. The north part of the county is drained by Big River, and most of the sout part is drained by the St. Francis River.

The three major structural and topographic divisions of the county—the mountains, the plain, and the hilly land in between—are incised by the St. Francis River enroute south. Shut-ins, cascades, and waterfalls over igneous rocks control the course, gradient, and flood plain features of this river. Big River, on the other hand, is a stream with incised meanders. Its early meandering across the Farmington Plain was followed by rejuvenation. Big River cut deeply into dolomite during the last rejuvenation, but the St. Francis River continued essentially unchanged due to the hardrock barriers. The difference in the nature of the two streams seems to lie in a relative resistance of the rocks to stream erosion.

how this survey was made

Soil scientists made this survey to learn what soils are in the survey area, where they are, and how they can be used. They observed the steepness, length, and shape of slopes; the size of streams and the general pattern of drainage; the kinds of native plants or crops; and the kinds of rock. They dug many holes to study soil profiles A profile is the sequence of natural layers, or horizons, i a soil. It extends from the surface down into the parent material, which has been changed very little by leaching or by plant roots.

The soil scientists recorded the characteristics of the profiles they studied and compared those profiles with others in nearby counties and in more distant places.



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general soil map units

The general soil map at the back of this publication shows broad areas, called soil associations, that have a distinctive pattern of soils, relief, and drainage. Each association on the general soil map is a unique natural landscape. Typically, an association consists of one or more major soils and some minor soils. It is named for the major soils. The soils making up one association can occur in other units but in a different pattern.

The general soil map can be used to compare the suitability of large areas for general land uses. Areas of suitable soils can be identified on the map. Likewise, areas where the soils are not suitable can be identified.

Because of its small scale, the map is not suitable for planning the management of a farm or field or for selecting a site for a road or building or other structure.

The soils in any one association differ from place to place in slope, depth, drainage, and other characteristics that affect management.

This general soil map is generally consistent with the general soil map of Missouri (*1*).

soil descriptions

1. Caneyville-Crider-Gasconade association

Deep to shallow, gently sloping to steep, well drained and somewhat excessively drained soils that formed in loess and clayey material

This association is in the part of the Farmington Plain that is dissected by Big River and its tributaries (fig. 4). The slope range is 2 to 35 percent.

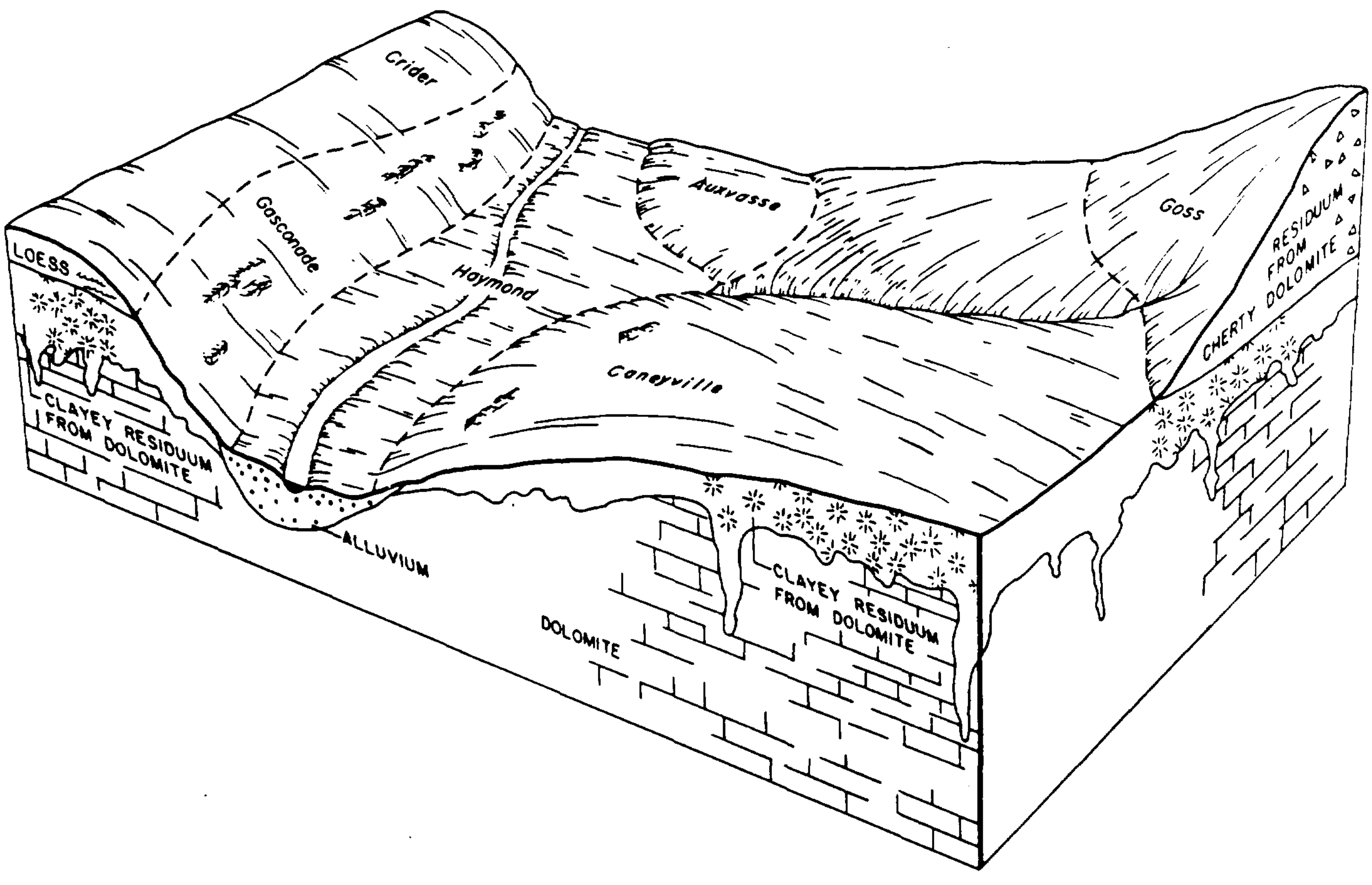


Figure 4.—Typical pattern of soils and parent material in the Caneyville-Crider-Gasconade association.

This association makes up about 23 percent of the county. It is about 49 percent Caneyville soils, 15 percent Crider soils, 8 percent Gasconade soils, and 28 percent soils of minor extent.

The Caneyville soils are moderately deep, gently sloping to moderately steep, and well drained. These soils are on uplands, commonly at a higher elevation than the Gasconade soils. They have a surface layer of dark brown silt loam and a subsoil of reddish brown and dark reddish brown silty clay and clay. They are underlain by hard dolomite at a depth of about 31 inches.

The Crider soils are deep, gently sloping to strongly sloping and well drained. These soils commonly are on ridges, but some areas are on side slopes or foot slopes. They have a surface layer of dark brown silt loam. The subsoil is brown silty clay loam in the upper part, reddish brown silty clay loam in the middle part, and red silty clay in the lower part.

The Gasconade soils are shallow, strongly sloping to steep, and somewhat excessively drained. These soils have a surface layer of very dark brown flaggy silty clay loam and a subsoil of dark brown very flaggy silty clay. They are underlain by dolomite at a depth of 13 inches.

Of minor extent in this association are deep, very cherty Goss soils and moderately well drained Hildebrecht soils on uplands. Well drained Haymond soils and moderately well drained Wilbur soils are on flood plains. Poorly drained Auxvasse soils are on terraces and benches. Sandy, somewhat excessively drained Psamments are in tailing ponds.

About 50 percent of this association is cleared. Most of the cleared areas are used for pasture. Corn, soybeans, and grain sorghum are grown on narrow bottoms and some ridges. Mixed hardwood forest and small prairies or glades, many of which are partly invaded by eastern redcedar, are in the steep uncleared areas. Several towns are within this mapped area.

The soils in this association, except those on the narrow bottoms and gentle upland ridges, generally are not suited to cultivated crops. These soils have only limited potential for orchards and specialty crops. Much of the acreage is suited to raising livestock. Slope and the hazard of erosion and the shallowness and droughtiness of the soil are the main problems in pasture and cropland management. Sites for livestock ponds are plentiful. However, suitable fill material for the dam commonly is outside the pond site, and on some sites chemical or other treatment is required to seal the pond.

The soils in this association are suited to trees. The woodland is dominantly eastern redcedar, chinkapin oak, black oak, and hickory. Production is commonly low. Shallowness to bedrock is a major limitation on side slopes. The steep slopes limit the use of logging equipment. Erosion is a hazard along logging roads and skid trails.

The soils in this association, except the Crider soils, are generally unsuitable for sanitary and building site development. Slope and depth to bedrock are the main limitations.

The soils are suited to use as habitat for openland and woodland wildlife. Increasing urban and residential development, however, is taking up land suitable for wildlife habitat, especially for woodland wildlife. Providing food for the wildlife is a major management concern.

2. Crider-Fourche-Nicholson association

Deep, gently sloping to strongly sloping, well drained and moderately well drained soils that formed in loess and clayey material

This association is part of the Farmington Plain (fig. 5). It is a broad rolling plain that separates the drainage areas of the north flowing Big River and the south flowing St. Francis River. The north part of the association is a karst area that borders the Ste. Genevieve fault. The slope range is 2 to about 14 percent.

Higher hills are along the north and south edges of the association and isolated hills are scattered throughout. Most of the area is drained by small streams, but a small acreage, mostly in the north part, is drained by sinks into the dolomite.

This association makes up 20 percent of the county. It is about 34 percent Crider soils, 23 percent Fourche soils, 14 percent Nicholson soils, and 29 percent soils of minor extent.

The Crider soils are gently to strongly sloping and well drained. These soils are on ridgetops and side slopes. They have a surface layer of dark brown silt loam. The subsoil is brown silty clay loam in the upper part, reddish brown silty clay loam in the middle part, and red silty clay in the lower part.

The Fourche soils are moderately sloping and strongly sloping. They are moderately well drained. These soils have a surface layer of brown silt loam. The subsoil is yellowish brown silt loam in the upper part, multicolored, mottled silty clay loam in the middle part, and yellowish red, mottled silty clay in the lower part.

The gently sloping and moderately well drained Nicholson soils are on ridges. These soils have a surface layer of dark brown silt loam. The subsoil is dark brown silty clay loam and yellowish brown, mottled silty clay loam that is underlain by a yellowish brown silt loam fragipan.

Of minor extent in this association are moderately deep Caneyville soils on the uplands. Well drained Haymond soils and poorly drained Auxvasse soils are on the bottom lands.

About 85 percent of this association is cleared. The cleared acreage is used for general farming. Pasture, hay, row crops, and small grains are grown. Wheat is the major small grain. The common crops—corn, grain sorghum, and soybeans—are grown throughout the association, but production of these crops is heaviest in the southern part. Alfalfa is grown for hay. Grasses and grass-legume pastures and hayfields are common. The

~~site preparation, by prescribed burning, or by spraying or cutting. There are no significant limitations to planting or harvesting trees.~~

~~This soil is suitable for building sites and septic tank absorption fields if proper design and installation procedures are used. In reservoir areas, exposed portions of the lower subsoil leak freely. Excessive seepage from lagoons, ponds, or lakes can be prevented by special treatment to seal the reservoir area.~~

~~This map unit is in capability subclass IIe and woodland ordination group 3o.~~

15C—Crider silt loam, 5 to 9 percent slopes. This deep, moderately sloping, well drained soil is on upland side slopes bordering small streams and drainageways. Individual areas are long, narrow, and parallel to streams or are leaf-shaped around the upper end of drainageways. Areas are commonly several hundred acres in size.

Typically, the surface layer is dark brown silt loam about 7 inches thick. The subsoil to a depth of about 72 inches is brown and reddish brown silty clay loam in the upper part and red and dark red silty clay in the lower part.

Included with this soil in mapping are small areas of the moderately well drained Fourche soils and the well drained Caneyville soils. These soils make up about 10 percent of the map unit.

Permeability is moderate, and runoff is medium. Available water capacity is high. Reaction ranges from very strongly acid to neutral in the subsoil, but varies widely in the surface layer as a result of local liming practices and erosion. Natural fertility is medium, and the organic matter content is moderately low. The surface layer is friable and easily tilled. There are no serious restrictions to root development throughout the solum.

In most places this soil is farmed or has been farmed. It is suited to corn, soybeans, grain sorghum, small grains, and grasses and legumes. If the soil is used for cultivated crops, erosion is a hazard. Minimum tillage, winter cover crops, terrace systems, contour tillage, and crop rotations reduce excessive soil loss. Returning crop residue or regularly applying other organic material helps improve fertility, maintain tilth, and increase water infiltration.

Pastureland or hayland are effective uses in controlling erosion on this soil. Overgrazing, however, causes erosion, surface compaction, excessive runoff, and poor tilth. Proper stocking, pasture rotation, and timely deferment of grazing help keep the pasture and the soil in good condition.

This soil is suited to trees, and a few small areas remain in native hardwoods. Tree seeds, cuttings, and seedlings survive and grow well if competing vegetation is controlled or removed by proper site preparation, by prescribed burning, or by spraying or cutting. There are no significant limitations to planting or harvesting trees.

This soil is suitable for building sites and for septic tank absorption fields if structures are properly designed and installed. Excess seepage from lagoons, ponds, and lakes can be prevented by special treatment to seal the reservoir area.

This map unit is in capability subclass IIIe and woodland ordination group 3o.

15D—Crider silt loam, 9 to 14 percent slopes. This deep, strongly sloping, well drained soil is on upland side slopes. Individual areas are irregularly shaped, commonly narrow and elongated, and 10 to 100 acres.

Typically, the surface layer is dark brown silt loam about 5 inches thick. The subsoil is about 63 inches thick. The upper part of the subsoil is reddish brown and yellowish red silty clay loam. The lower part is red silty clay and is underlain by dolomite or dolomitic limestone at about 68 inches. In spots, erosion has removed the surface layer, exposing the silty clay loam. In several places, erosion has created gullies. In some small areas the depth to hard rock is less than 60 inches.

Permeability is moderate, and runoff is medium. The available water capacity is high. Reaction ranges from neutral to very strongly acid in the subsoil. Natural fertility is medium, and the organic matter content is low. The surface layer is friable and easily tilled. Eroded spots can make seedbed preparation difficult.

In most areas this soil is used for pasture and hay. A few small areas are in trees. Most open fields have been used for cultivated crops. This soil is suited to corn, soybeans, and grain sorghum but is seldom used for these crops because erosion is a severe hazard and eroded spots are common.

Some areas have been severely eroded from past use. Terrace systems, crop rotation, minimum tillage, contouring, and winter cover crops reduce excessive soil loss. Returning crop residue to the soil and adding other organic material help to improve fertility, maintain tilth, and increase water infiltration. These practices are especially important for renovation of eroded areas.

Pastureland and hayland, if well established and maintained, are effective uses in controlling erosion. Overgrazing, however, can cause surface compaction, excessive runoff, and poor tilth. Proper stocking, pasture rotation, and timely deferment of grazing help keep the pasture and the soil in good condition.

There are no severe limitations to planting and harvesting trees. Plant competition is moderate. It can be reduced by site preparation, spraying, or cutting.

This soil is suitable for use as a building site and for use as septic tank absorption fields if structures are properly designed and installed. The steepness of slope can be offset for these uses by landscaping and designing structures to fit the slope. The lower part of the subsoil is kaolinitic clay. If it is exposed in a reservoir area, seepage is a hazard. Excess seepage from lagoons, ponds, and lakes can be prevented by special treatment to seal the reservoir area.

This map unit is in capability subclass IVe and woodland ordination group 3o.

This soil is suited to both native hardwood trees and shortleaf pine. Rooting depth is limited by the fragipan, and there is a slight windthrow hazard depending on the thickness of the soil above the fragipan. Harvesting mature trees eliminates those most susceptible to windthrow. Surface stoniness is a moderate limitation to the use of tree planting equipment. In some areas it may be necessary to plant seedlings by hand or use direct seeding.

This soil is suitable for building site development and onsite waste disposal if structures are properly designed and installed. Dry basements can be maintained if excess water is drained and the basement walls are adequately sealed. Low strength and poor stability for vehicular traffic can be corrected by strengthening or replacing the base material. This soil is generally unsuitable for septic tank absorption fields because of very slow permeability and seasonal wetness. Slope is a limitation for sewage lagoons but can be overcome by careful site selection and proper design and construction. Sites can be graded to modify the slope.

This map unit is in capability subclass VIe and woodland ordination group 4x.

18—Dumps, mines. This miscellaneous area consists of chat dumps of dolomitic material that was crushed to gravelly coarse sand during lead mining. The dumps are very steep (slopes ranging from about 20 to 50 percent), white, dome-shaped hills that are 50 to 250 feet high and 30 to more than 100 acres (fig. 13).

This excessively drained dolomitic material does not show any significant alteration by weathering. It is gray, grayish brown, or light brownish gray coarse sand or fine

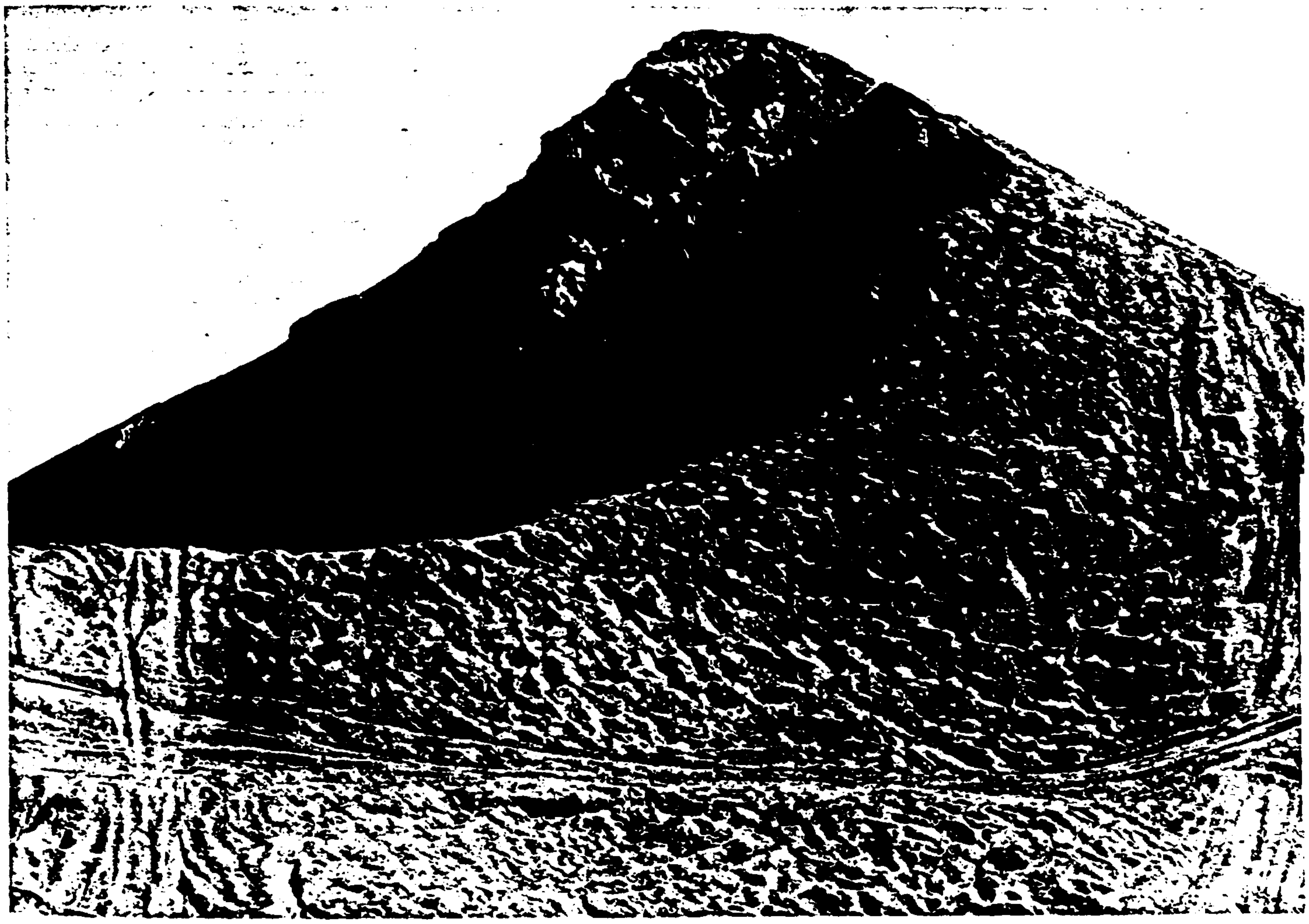


Figure 13.—The chat dumps are unique manmade landforms, reminders of early lead mining in the county.

gravel (2 to 10 millimeters in diameter). It is similar to Psamments, 0 to 9 percent slopes; however, it is much steeper and more droughty and does not support vegetation.

Permeability is very rapid, and even though the dolomitic material is very steep most precipitation is absorbed into the surface. Available water capacity is very low. The material is mildly or moderately alkaline throughout and effervesces when treated with dilute hydrochloric acid. It does not have a sufficient balance of nutrients to support plants. Organic matter content is very low or essentially nonexistent.

This material is used as a source of agricultural lime (fine portion), road material (coarse portion), asphalt mix, and fill material. It has long been a distinctive landmark of the old "Lead Belt Area," which has gained some measure of esthetic value. It captures the attention of travelers both on the ground and in the air. In recent years, some dumps have been used as recreation areas for off-the-road vehicles and hikers and as launching sites for hang gliders. Small communication towers are on the summit of several dumps.

In their present condition these areas have no apparent potential for supporting plants. Slight drifting and blowing of dust is difficult to overcome without major and costly reclamation. The dolomitic material is not suitable for building sites and sanitary facilities because of the steepness of slopes. The material, when leveled, is stable and suitable for building sites. It is a source of sand but needs screening to separate excess fines.

This map unit is not assigned to interpretive groupings.

19A—Elsah silt loam, 0 to 3 percent slopes. This deep, nearly level, well drained soil is on narrow branch and creek bottoms. It is subject to frequent flooding. Individual areas of this map unit are commonly long, narrow strips that range in size from 20 to more than 200 acres.

Typically, the surface layer is very dark grayish brown silt loam about 6 inches thick. A transition layer below that is brown silt loam about 12 inches thick. The substratum to a depth of 60 inches or more is brown and yellowish brown very cherty loam. In some places the dark surface layer is more than 10 inches thick. Also, in some areas the depth to cherty alluvium is more than 24 inches. Some areas contain more sand.

Included in mapping and making up about 15 percent of the map unit are areas of the somewhat excessively drained cherty Midco soils and a few small areas of the well drained Ashton soils. Midco soils are adjacent to the stream channel and Ashton soils are on high bottoms or foot slopes.

Permeability is moderate in the upper 18 inches and moderately rapid in the lower part of the profile. Surface runoff is slow. Frequent, very brief periods of flooding occur in winter and spring. Available water capacity is moderate. Reaction ranges from neutral to medium acid. Natural fertility is medium, and organic matter content is moderately low. The surface is friable and easily tilled. Root development is restricted slightly by the cherty substratum.

Most areas of this soil are cleared and used for pasture. Only a small acreage is cultivated. This soil is suited to corn, soybeans, small grain, grasses, and legumes but is subject to flooding and droughtiness. The hazard of flooding is most severe in early spring. Clearing the stream channel of obstructions and using dikes, levees, and diversions help prevent excess flooding and scouring. Returning crop residues to the soil or adding other organic material on a regular basis help to improve fertility, reduce crusting, and increase water infiltration. Pasture can be kept in good condition by proper stocking, pasture rotation, and timely deferment of grazing.

This soil is suited to trees, and a few areas remain in native hardwoods. Plant competition and seedling mortality are moderate. Tree seeds, cuttings, and seedlings survive and grow well if competing vegetation is controlled or removed. This can be accomplished by site preparation, by prescribed burning, or by spraying or cutting. Using special planting stock of a larger size than usual may be necessary to improve the survival rate.

This soil generally is not suited to building site development or to onsite waste disposal because of the flooding hazard. This can be partly overcome by the use of dikes, levees, or by filling.

This map unit is in capability subclass IIs and woodland ordination group 3f.

20C—Fourche silt loam, 5 to 9 percent slopes. This deep, moderately sloping, moderately well drained soil is on side slopes, points, and some rounded ridgetops. Areas are irregular in shape and range from 20 to several hundred acres in size.

Typically, the surface layer is brown silt loam about 7 inches thick. The subsoil to about 60 inches is yellowish brown silt loam and brown silty clay loam in the upper part, yellowish red silty clay loam in the middle part, and yellowish red and strong brown, mottled silty clay in the lower part. In places, the surface layer is silty clay loam because severe erosion has removed most or all of the original topsoil. In some places the depth to bedrock is less than 60 inches.

Included with the soil in mapping are small areas of the moderately deep Caneyville soils, which make up about 10 percent of the unit.

Permeability is moderately slow, and runoff is medium. Available water capacity is high. Reaction in the upper part of the subsoil is very strongly acid to medium acid, but in the lower part it ranges from very strongly acid to mildly alkaline. Reaction in the surface layer varies widely as a result of erosion and local liming practices. The surface layer is friable and easily tilled, but tillage and other farming practices may be delayed from several days to two weeks by numerous seepy spots and by a seasonal high water table which is at a depth of 1.5 to 3 being restored and planted to trees or grasses. Stony, uneven areas generally are unsuitable for most farming purposes. In most areas, Orthents have a fair potential for trees and wildlife habitat. Limitations for building site development are severe and can be overcome only by major landscaping and reclamation of the site.

This map unit is not assigned to an interpretive grouping.

36C—Psamments, sloping. This map unit consists of deep, nearly level to gently rolling, somewhat excessively drained, newly formed soil on low slopes and in tailing ponds. Individual areas are commonly somewhat oval or irregular in shape and are large. Most of the acreage is in only a few areas ranging from about 400 to more than 1,000 acres. A few small areas are scattered in the vicinity of the large areas. These soils are formed in crushed dolomitic material from lead mining.

Typically, the surface layer is brown loamy fine sand about 1 inch thick. Below this is a thin transitional layer of pale brown loamy fine sand about 1 inch thick. The underlying material is light gray loamy fine sand, stratified by thin lenses of light brownish gray silt loam or very fine sandy loam amounting to about 10 percent of the mass. It extends to 60 inches or more and is mildly alkaline throughout.

Permeability is rapid, and surface runoff is slow to medium although most precipitation is absorbed into the surface. The available water capacity is low. Reaction is mildly or moderately alkaline throughout. The natural fertility is very unbalanced, and careful fertilization is required to make the soil more suitable for plant growth. The organic matter content is very low. Some areas of the tailing ponds are subject to frequent flooding.

Most areas of these soils have essentially been abandoned since mining ceased. Some areas have been seeded to grasses and legumes but results are poor. These soils are generally unsuitable to growing grasses, shrubs, and trees unless intensively managed. The most important need in managing the soil is to establish a vegetative cover. This may be done by assuring adequate available moisture, carefully selecting plants, balancing fertility, and protecting the soil from blowing. Moisture conservation practices or sprinkler irrigation are also helpful. Plants that require or tolerate soil that is alkaline and contains lime should be chosen. Fertilizer needs include nitrogen, phosphates, potash, and possibly some trace elements. Temporary operations such as rough tillage or mulching may be adequate to protect young plants from abrasion by blowing soil.

Because it is very difficult to establish any kind of vegetative cover, there is a lack of essential wildlife habitat elements such as food, water, and cover. Once cover is established, wildlife potential can improve.

Most of the acreage is not suited to recreation uses because of flooding. In areas not subject to flooding the sandy textures and blowing are limitations. Vegetative cover is essential for areas used for camping, picnicking, and playgrounds. Spreading a thin layer of topsoil may be necessary to assure vegetation of critical areas.

These soils are generally unsuitable for building site development and onsite waste disposal because of the hazard of flooding. Areas free of the flooding hazard are suitable for building sites. Rapid permeability may allow effluent from sanitary facilities to contaminate ground water. Detailed onsite investigation is needed in any area considered for building sites.

This map unit is not assigned to interpretive groupings.

37E—Ramsey very stony sandy loam, 14 to 35 percent slopes. This shallow, moderately steep and steep, somewhat excessively drained soil is on side slopes. Individual areas of this map unit are irregular in shape and range from 20 to several hundred acres in size.

Typically, the surface layer is very dark grayish brown very stony sandy loam about 2 inches thick. A brown sandy loam subsurface layer is about 3 inches thick. The subsoil is strong brown cobbly sandy loam and is underlain by hard sandstone at 16 inches. Some areas are not stony.

Included with this soil in mapping, and making up about 10 percent of the map unit, are moderately deep, well drained Lily soils which are on foot slopes, benches, and lesser slopes.

Permeability and runoff are rapid, and available water capacity is very low. Organic matter content and natural fertility are both low. Reaction in the subsoil is very strongly acid or strongly acid. Rooting depth is 7 to 20 inches and is limited by sandstone except for occasional fractures in the bedrock.

Most areas of this soil are in timber. A few areas are cleared and used for pasture. This soil is suited to trees, but production is low. Intensive timber management is not common because erosion hazard, equipment limitations, and windthrow hazard are severe. Droughtiness and low fertility are also limitations that cannot easily be overcome. Planting seedlings on north and east slopes helps overcome the drying effect of aspect. The erosion hazard and equipment limitations can be partly overcome by careful selection, preparation, and maintenance of roads and skidding trails. Timely harvesting of mature trees limits windthrow.

Some of the less stony and less steep areas are used for pasture. This Ramsey soil is suited to some grasses and legumes. It is droughty because of low available water capacity and water loss by runoff. Maintaining an adequate vegetative cover helps to prevent excessive soil loss and reduce runoff. Overstocking and overgrazing reduce the protective cover and increase runoff and erosion. Native grasses are desirable for summer grazing. Proper stocking, uniform grazing distribution, timely deferment of grazing, and a planned grazing system help to keep the pasture and the soil in good condition. Some areas are suitable for pond reservoir sites but there may be no soil material suitable for a dam.

RECORD OF COMMUNICATION

☒ TELEPHONE CONVERSATION

☒ INCOMING ☐ OUTGOING

☐ MEETING

DATE: 1/12/93

TIME: 9:00 AM/PM

RECORDED BY: L Splichal

PROJECT: National tailings

CONTRACT NO.

SUBJECT: Wells

PARTICIPANTS	ORGANIZATION/DEPARTMENT	TELEPHONE/EXT.
John Schumacher	USGS-Rolla	(314) 341-0838
Laura Splichal	CDM Federal	(913) 492-8181

SUMMARY:

The static water level in the Gumbo well (PWSD#1) measured by the USGS is 111.7' BGS. Elevation of the well is 806' BGS.

The private well list sent to me was compiled by the DGLS. Contact Michelle Widener for info - 368-2318 (314).

He would like for me to send him info on PWSD#2 well and distribution when we receive it.

DISTRIBUTION: ☐ PARTICIPANTS ☒ FILE

OTHER:

	INFORMATION	ACTION
	☐	☐
	☐	☐
	☐	☐

CDM Federal Programs Corporation — RECORD OF COMMUNICATION

[X] TELEPHONE CONVERSATION — DATE: 1/12/93

[ ] INCOMING [X] OUTGOING — TIME: 6:00 AM/PM (PM circled)

[ ] MEETING — RECORDED BY: L. Splichal

PROJECT: National mine tailings CONTRACT NO.

SUBJECT: PWSD #1 in Gumbo, MO

PARTICIPANTS	ORGANIZATION/DEPARTMENT	TELEPHONE/EXT.
Van Rawson	PWSD #1 (operator)	(314) 431-0046
L. Splichal	CDM Federal	(913) 492-8181

SUMMARY:

PWSD #1 well is located in Gumbo, MO and serves the residents of Gumbo and persons who live along Hwy 8 east to Owl Creek and west to the old RR bed that is now Halsey Road. The system has 56 connections, 48 of these are active. He cannot give me a copy of his latest analytical data without consulting the board. Poplar Bluff is the regional MDNR office, however, and they would have the information.

DISTRIBUTION: [ ] PARTICIPANTS [X] FILE — INFORMATION — ACTION

OTHER:

1/3/89 — ae021

Gumbo, MO WELLS

12/1/69

MISSOURI GEOLOGICAL SURVEY AND WATER RESOURCES, ROLLA, MISSOURI

COUNTY St. Francois

MGS LOG NO. 26542

COMPANY OR OWNER St. Francois Co. Water Dist. #1

FARM [illegible]

WELL NO. 1

LOCATION NW SEC 2 T 36N R 4E

CONTRACTOR Lonnie Goggins

DRILLER

COMMENCED

COMPLETED 2/70

PRODUCTION 60 gpm w/100' DD

CASING RECORD 400' of 6" ID csg., grouted w/170 sacks cem.

WATER RECORD

SOURCE OF LOG

REMARKS

Resi. & Orig.

ELEV. Sab Keeney 6-6-73 [illegible]

TOTAL DEPTH 565'

SWL 400'

NO. SAMPLES 75

FORMATION	FROM (FT)	TO (FT)	FORMATION	FROM (FT)	TO (FT)
No samples	0	190			
Bonneterre	190	440			
Lamotte	440	565			

CDM Federal Programs Corporation

RECORD OF COMMUNICATION

☒ TELEPHONE CONVERSATION

☐ INCOMING ☒ OUTGOING

☐ MEETING

DATE: 1/7/93

TIME: 10:00 AM/PM

RECORDED BY: L Splechal

PROJECT: National Mine Tailings CONTRACT NO.

SUBJECT: Flat River Municipal Water System

PARTICIPANTS	ORGANIZATION/DEPARTMENT	TELEPHONE/EXT.
Ron Warren	Flat River Water Dept.	(314) 431-2280
Laura Splechal	CDM Federal	(913) 492-8181

SUMMARY:

Annual production rates for each well (1992):

North mine well = 201,912,000 gal = 42.9%
South mine well = 155,813,000 gal = 33.1%
$\Big\}\Rightarrow$ 76%

Desloge well = 113,014,000 gal = 24.0%

The two wells in the mine shaft at Rivermines are cased to 416 feet. From 416-435 is open, therefore the water comes from the LaMotte Formation. The Desloge well is cased to 385 feet. From 385-765 feet is open; this well also draws from the LaMotte Formation. Water from the mine wells goes to the treatment plant where it is run through rapid flow gravity sand filters, treated with potassium permanganate to remove iron, and treated with the chlorination & fluoridation equipment. Water from the Desloge well does not go to the treatment plant, but is blended directly into the system. Two other locations

DISTRIBUTION: ☐ PARTICIPANTS ☒ FILE

OTHER:	INFORMATION	ACTION
Rob Parsons	☐	☐
Doug Updike	☐	☐
	☐	☐

near the mine wells have casings set into the mine. Pumps could be installed at these locations to provide additional water supply if required.

Mining a New Future

FACTS ABOUT THE CITY OF FLAT RIVER MISSOURI

Published by Fact Books, Inc., Arnold, MO 63010

ıent for some training expenses. e regional Missouri Job Service f qualified applicants and offers and interviewing of prospective

operty	12%
perty	19%
perty	32%
rty	33.3%

n all commercial property). king from established guidelines, to determine what is agricultural nmercial property. The State of e tax rates.

for the City of Flat River is 1.19/ e total assessed value of city

a unique opportunity for entre- s people to develop industrial, s. As a commitment to realizing y of Flat River applied for and ıll-time Economic Development of Missouri's Rural Communities The City has contracted with the ovide office space, secretarial ıte a comprehensive economic Mineral Area.

Coordinator of the Mineral Area, e Flat River Area Chamber of st with the development of our vork with any business wishing ssets of the area. The Economic ains listings on available build- ld be happy to provide more any's specific needs. In the Flat ead community support – people new opportunities afforded by

velopment Coordinator
r

The Water System

The City of Flat River has owned and operated its water system since 1973 at which time it was purchased from the Lead Belt Water Company. The water treatment plant was constructed in 1925 with major renovations in 1957 and 1989. The plant principally includes pumps, rapid flow gravity sand filters, chlorination equipment and fluoridation equipment. The system has a daily production capacity of approximately 3,085,000 gallons per day. The City currently uses a yearly average of about 1,259,000 gallons of water per day and has a maximum daily usage rate of about 1,770,000 gallons of water per day.

The City has a total treated water storage capacity of 1,090,000 gallons. City owned storage facilities include a 200,000 gallon elevated steel tank, located in Desloge, a 390,000 stand pipe located on East Main Street in Flat River, and a 500,000 gallon elevated tank in the Industrial Park.

The City's transmission and distribution system consists of 408,390 feet of pipe.

The supply of water for the water system is the abandoned flooded mines in Rivermines. Water reserve in the mines is estimated at 70 billion gallons. Water is pumped from the mines by means of two 1,500 gallon per minute pumps located at a pumping station, constructed in 1973. The City has two cased holes in the mines which could be used for additional water supply if required.

The Flat River water system serves the surrounding communities of Desloge, Elvins, Esther, Federal, Leadington, Rivermines, and Flat River. The system currently serves 4,779 customers. ? Pop is 13,095 people. (1990) Service connections 4707. (3/92)

Sanitary Sewer System

The City of Flat River's sanitary sewer system was originally constructed in the 1930's, expanded in 1964 and again in 1982. The system is composed of some 40 miles of sewers, seven lift stations, and a new modern oxidation ditch treatment plant. This new treatment plant was placed in operation in 1985.

The City of Flat River operates and maintains the sewer collecting systems for Desloge, Elvins, Esther, Leadington, Rivermines, and Federal. The new treatment plant was built as a regional treatment facility and treats the sewerage from all seven communities. The regional treatment plant was designed for 2.05 MGD (million gallons per day) with maximum flow design of 4.7 MGD. Our present daily flow is 1.24 MGD which would allow for major expansion.

12-15-92

to the water department.

1300 At Water Dept. on Main St. Speaking with Barry McCord, the Administrative Assistant. (314) 431-2280. The Flat River-Desloge municipal system serves residents of Desloge, Leadington, Flat River, Elvins, Rivermines, and Esther. Two nested wells are located in Rivermines in an old mine shaft and draw water from the mine. A third well is located in Desloge north of Locust Street that is a drilled well and is used for backup. We need to talk to Ron Warren, Superintendant for the latest analytical results, pumping rates, and well logs.

1315 At City Hall while waiting for Mr. Warren to return. Bill Priest, Building Inspector, provided us with the owners of the lots on Buckley Street

who are the nearest residents to the chat pile. He also gave us a Flat River city map. His # is (314) 431-3577.

1330 Meet with Ron Warren. There are no rural water supplies outside the city limits. Rural residents have their own wells. The two nested mine wells are 416' deep. 1500 gpm is capacity pumpage from each well. The pumps are set at 100' BGS and the water level is at 45' BGS. There is no drawdown from these wells! Estimated recharge is 10,000 gpm. The Desloge well is 765' deep and was installed in 1969. 340 gpm is pumped from this well, the pump is set at 375' BGS. The nested wells are the primary water source for the municipal system. The Desloge well is pumped some during winter months to keep the well fresh. It is used more in the summer when demand for water is greater. Water from both sources go to the treatment plant. Water from the mine wells is treated with potassium permanganate to remove iron. This treatment system has been needed since 1983 when excessive iron was first noted in the mine water. After treatment the water is blended with untreated water from the Desloge well and distributed. Mr. Warren reported that the lower alluvial portion of the pile was previously a tailings pond that was dammed to prevent drainage to Flat River. The dam is now washed out, and fine sediment is free to enter Flat River.

1352 Copying most recent analytical data and Desloge well log.

1357 Obtained city history info. from the Chamber of Commerce located next door to the Water

Department.

1400 Departing for Bonne Terre.

1420 At City Hall meeting with Terrance Rickart, the City Manager. No plat maps are available for Bonne Terre because there are no property taxes. He recommended several references for us to get on geology and mining history. Turkey Creek is surface water drainage from Bonne Terre.

1445 Laina is at Chamber of Commerce in Bonne Terre to obtain historical info. on the town.

1455 Departed for the mine. Noting nearest businesses and residences to the Bonne Terre Chat Pile:

Egyptian Concrete 358-2773

Mid Western Trust Co 1800-392-3444 (since 1968).

Bluff City Beer Co. Since 1933

Bonnie Bowl Cocktail Lounge

Mini-mall consisting of Classic Video, Radio Shack, and the Ice

Source: Missouri Dept. of Natural Resources
Dept of Geology and Land Survey
(MDNR-DGLS 1992)

Michelle Wideener 308-2318

REFNUM	OWNER_LAST	OWNER_FRST	OWN_ADD_1	CITY	DATE_COMPL	REGNOW	CASING_L	TEST_YLD	SWL	USE	Q_2	Q_3	SEC	TWN	RNG	TOTAL_DPTH
12590A	WILLIAMS	JOHN	705 WESTWOOD DRIVE	FLAT RIVER	01/18/89	A00042	80	30	120	D				36N	04E	574
47032A	FULTS	BOB	RR 1, BOX 544	ELVINS	06/28/90	A00040	80	24	220					36N	04E	300
41964A	BARBEE	TERRY		IRONDALE	08/15/90	A00033	80	17	150	D				36N	04E	200
44268A	STRANGE	CARL	1001 E MAIN	FLAT RIVER	09/01/89	A00042	80	25	140	D		✓	01	36N	04E	533
55091A	SHORES	DONNA	RT 33 BOX 38	FLAT RIVER	03/26/91	A00332	80	30	30		NW	NW	01	36N	04E	364
13559A	WARREN	JACK	P.O. BOX 1548	No ✓DESLOGE	05/14/89	A00141	0	0	0	D	SE	NW	02	36N	04E	140
14426A	CONWAY	TODD	RT. 1 BOX 394	ELVINS	08/25/87	A00042	80	12	92	D	✓NE	NW	02	36N	04E	451
03430A	ADAMS	RODNEY	RT.1 BOX 358C	FLAT RIVERS	07/02/87	B00026	80	100	0	D			02	36N	04E	246
03545A	ADAMS	RODNEY	RT. 1 BOX 358 C	FLAT RIVER	07/13/87	C00064	0	0	0	D			02	36N	04E	0
06244A	SLADE	CHARLES E.	RT. 4, BOX 278	FARMINGTON	04/10/88	A00033	82	30	60	D		NE	02	36N	04E	410
40373A	PAPAYIK	SAM	P.O. BOX 361	FLAT RIVER	09/22/88	A00042	80	100	120	D		NE	03	36N	04E	400
05324A	MULLEN	PAT	BOX 544	CUBA	02/16/88	A00106	126	14	0	D	NE	NE	04	36N	04E	190
55095A	STANFROD	JOHN	RT 1	ELVINS	04/17/91	A00332	80	30	120		NW	SE	04	36N	04E	28[illegible]
55469A	ADAMS	BRUCE	800 MONROE ST	No ✓DESLOGE	08/12/91	A00332	80	20	60	D	SW	NW	05	36N	04E	20[illegible]
11404A	FRIEND	BYFORD	RT. 33, BOX 184	FLAT RIVER	03/28/88	A00042	80	10	0	D	SW	NW	06	36N	04E	287
60016A	FRIESE	BILL	RT 33 BOX 182	FLAT RIVER	06/03/91	A00042	80	25	85	D			06	36N	04E	207
67841A	SWEET	DENIS & ELLEN	RT 1 BOX 605A	MINERAL POINT	10/01/91	A00332	80	10	100	D	NW	SW	06	36N	04E	304
08254A	TALLMAN	RANDY	C/O FIRMIN GETTINGER	POTOSI,	04/29/88	A00042	80	8	80	D	NE	NE	07	36N	04E	287
15344A	STEVENS	JACOB B.	RT. 1, BOX 202F	IRONDALE	06/09/89	A00059	84	0	230	D	NE	NW	07	36N	04E	362
40393A	MOSIER	JAMES	RT 1 BOX 198	IRONDALE	11/28/89	A00042	80	15	80	D			07	36N	04E	266
61534A	PROVINCE	HAROLD GENE	RT 33 BOX 376	FLAT RIVER	02/05/92	A00049	82	12	150	D	SE	SW	07	36N	04E	289
13830A	MCMULLIN	ERNEST	RT 33 BOX 533	FLAT RIVER	04/29/89	C00212	0	0	0	D	SE	NW	09	36N	04E	130
06069A	LAWSON	DALE	1927 LYNCH	ST. LOUIS	01/18/88	A00042	80	20	240	D	SE	SE	09	36N	04E	349
27971A	LASHLEY	JIM	BOX 530 RT.33	FLAT RIVER	06/01/89	C00212	0	0	0	D	NE	SE	09	36N	04E	130
41899A	BARLO	MYRA	BOX 886	FLAT RIVER	02/07/90	A00033	80	20	225	D			10	36N	04E	0
44222A	MARLER	ROGER	810 7TH ST	ESTHER	06/29/89	A00042	80	17	0	D	SW	SW	11	36N	04E	307
					09/30/87	A00042	80	15	80	D	SW	SW	12	36N	04E	328
				'ER	10/12/87	A00042	80	25	40	D	SE	SE	12	36N	04E	285
				'ER	[illegible]	[illegible]	[illegible]	5	80	D			12	36N	04E	260
				'ER	[illegible]	[illegible]	[illegible]	0	0	D	SE	NW	13	36N	04E	615
					[illegible]	[illegible]	[illegible]	0	40		NE	NE	13	36N	04E	160
					[illegible]	[illegible]	[illegible]	[illegible]	60	D	NE	NE	13	36N	04E	140
				/ER	[illegible]	[illegible]	[illegible]	[illegible]	80	D	NE	NE	13	36N	04E	450
					[illegible]	[illegible]	[illegible]	[illegible]	0	D	NE	SW	13	36N	04E	328
				:S	[illegible]	[illegible]	[illegible]	[illegible]	200	D	SE	SE	14	36N	04E	430
				/ER	[illegible]	[illegible]	[illegible]	[illegible]	60	D	SE	SE	14	36N	04E	303
				/ER	[illegible]	[illegible]	[illegible]	[illegible]	200	D	SW	SE	14	36N	04E	389
					06/18/87	A00042	80	40	90	D	SW	SE	14	36N	04E	266
					08/20/90	A00332	80	10	180		SE	SW	14	36N	04E	324
				/ER	03/05/91	A00042	80	20	230	D	NE	NW	14	36N	04E	460
					01/23/92	A00332	80	5	200	D	SE	SE	14	36N	04E	568
				;	04/07/92	A00332	80	20	120	D	NW	SW	14	36N	04E	244
					03/27/92	A00042	80	15	0	D	SE	SE	14	36N	04E	243

WELL TYPE

D = Domestic
I = Irrigation
F = multiple Family (usually Trailer Park) > 3 Hookups
O = other (misc)
M = monitoring
H = Heat pump
SN = Survey No. (locate # on county map)

Actual Number of Wells Identified by (Sec, T, R) within 4-mile Radius

91 of which 39 ~~40~~ [illegible] 2-miles

[illegible]A	GOVREAU	TODD	816 MORRIS	FARMINGTON	10/02/87	A00042	60	10	0	D	SE	NW	28	36N	04E		250
[illegible]224A	PALMIER	JIM	BOX 488, RT. 1	ELVINS	09/01/87	A00042	0	0	0	D	NW	NE	28	36N	04E		0
52242A	WEST	GEORGE	917 W MAN	BISMARCK	04/01/91	A00049	82	75	15	D	NW	SW	28	36N	04E		165
02985A	SHIPMAN	JASON	RT 1 BOX 587	BISMARCK	08/28/87	A00042	80	20	40	D	SE	NE	32	36N	04E		170
44256A	MEADOR	GLEN	P.O. BOX 161	BISMARCK	09/12/89	A00042	80	20	20	D	SW	SW	32	36N	04E		184
44272A	HEDRICK	EARL	P.O. BOX 161	BISMARCK	08/15/89	A00042	80	20	0	D	SE	SW	32	36N	04E		164
40403A	TAYLOR	DWAIN	RT. 1, BOX 958	BISMARCK	04/10/90	A00042	40	2	0	D	SW	SE	32	36N	04E		923
86571A	BENNETT	STANLEY E	PO BOX 131	BISMARCK	06/11/92	A00332	0	0	0	D	NW	NW	33	36N	04E		208
52233A	MANION	KEVIN	RR 1	ELVINS	12/17/90	A00049	84	30	370	D	NE	SE	36	36N	04E		435
17018A	RONEY	GLEN	RT. 1, BOX 458-D	ELVINS	08/28/87	A00042	150	12	50	D			SN	36N	04E		250
04353A	MILLER	ERWIN	RT. 6, BOX 6119	FARMINGTON	/ /	C00052	0	0	50	D				36N	05E		0
08295A	RODERICK	AL	RT. 2, BOX 2199	FARMINGTON,	04/12/88	A00042	80	25	240	D	NE	NE		36N	05E		636
44257A	NEAVILLE	DON	129 ROSENER ROAD	FLAT RIVER	08/18/89	A00042	80	75	80	D				36N	05E		410
40413A	SEBASTION	GEORGE	ROUTE 2, BOX 2194	FARMINGTON	01/11/90	A00042	80	25	80	D				36N	05E		307
43739A	AUBUCHON	NATALIE A	BOX 142	FLAT RIVER	09/19/89	A00033	43	3	440	D			00	36N	05E		510
65117A	[illegible]ON	HELEN	RT 2	FARMINGTON	07/11/91	A00042	80	25	160	D	SE	SW	01	36N	05E	DMIT	34855
86577A	HAMMOND	JAMES	106A COMMONWEALTH	FLAT RIVER	07/09/92	A00332	0	0	0	D	SE	NW	01	36N	05E		310
11587A	BORDERS	JAMES F.	RT2 BOX 2436	FARMINGTON	07/02/87	A00042	80	25	100	D			02	36N	05E		410
53834A	WILLIAMSON	JEFF	RT 2 BOX 2198	FARMINGTON	03/30/90	A00042	80	15	0	D			02	36N	05E		410
65136A	BOREN	DARRELL	R R 2 BOX 2424-7	FARMINGTON	07/24/91	A00042	80	30	80	D	SW	SW	02	36N	05E		36[illegible]
06203A	DECKER	GARY W.	RT. 2 BOX 2208	FARMINGTON	10/19/87	A00042	80	10	0	D	SE	SE	03	36N	05E		3[illegible]
52228A	LAPLANTE	PETE	515 E MAIN	FLAT RIVER	11/02/90	A00049	82	60	150	D	NW	SW	03	36N	05E		5[illegible]
42579A	KING	ROD	RT 2 BOX 2178	FARMINGTON	10/16/90	A00332	80	20	50	D	NW	SE	03	36N	05E		2[illegible]
55466A	JOHNSON	MIKE	R R 2 BOX 25120	FARMINGTON	08/09/91	A00332	80	20	60	D	SW	NW	03	36N	05E		2[illegible]4
65133A	HARRIS	RICHARD	P O BOX 905	FLAT RIVER	07/29/91	A00042	80	30	0	D		SW	03	36N	05E		26[illegible]
67856A	RHODES	JOHN	RT 2	FARMINGTON	01/20/92	A00332	80	20	50	D	SW	NW	03	36N	05E		284
67876A	GRAHAM	RONALD E	RT 2 BOX 2452	FARMINGTON	03/20/92	A00332	85	20	50	D	NW	SW	03	36N	05E		324
11410A	MINKEL	LLOYD	RT. 3BOX 3940	FARMINGTON	05/03/88	A00042	80	45	0	D	NW		04	36N	05E		287
01492A	JOHNSON	DON	P.O. BOX 431	FARMINGTON	06/11/87	A00033	80	28	140	I			04	36N	05E		340
07080A	MINKLE	CONSTRUCTION	RT. 4, BOX 355	FARMINGTON	05/06/88	A00026	80	30	30	D	NW	NE	04	36N	05E		266
08289A	SEBASTIAN	GEORGE	P. O. BOX 315	FLAT RIVER,	05/05/88	A00042	80	23	80	D	SW	SW	04	36N	05E		348
43082A	TERRY	TOM	RT. 2, BOX 2521-K	FARMINGTON	12/13/89	A00042	80	40	0	D	NE	SE	04	36N	05E		266
53815A	NICHOLSON	TOM	606 4TH STREET	ESTHER	09/12/90	A00042	80	40	0	D		SE	04	36N	05E		289
31640A	WILDER	MARK	AND JOHN DEBOLD	FLAT RIVER	07/07/89	A00033	30	25	180	D			04	36N	05E		180
87535A	RIDLON	GARY	601 3RD ST	ESTHER	07/14/92	A00042	0	0	0	D	SE	SW	04	36N	05E		287
08291A	HELMS	BARRY	7 DAVIS COURT	FLAT RIVER,	04/18/88	A00042	80	10	241	D	NE	NE	06	36N	05E	1	540
44269A	SHANNON	BOB	601 WILLIAMS	FLAT RIVER	09/20/89	A00042	80	15	130	D			06	36N	05E		300
04727A	CUNNINGHAM	JIMMY	RT. 2 BOX 2064	FARMINGTON	01/29/88	A00033	80	20	160	D	SE	SE	09	36N	05E		400
05280A	LOGOMASINE	JAMES C.	1171 BIG BEN ROAD	BALLWIN	02/05/88	A00033	82	55	200	F		SE	09	36N	05E		510
07603A	AMSDEN	WILLIAM JR	ROUTE 4 BOX 362A	FARMINGTON	03/18/87	C00052	0	0	0	D			09	36N	05E		0
10461A	JONES	DAN	RT. 2	FARMINGTON	06/25/88	A00033	82	20	185	D			09	36N	05E		385
10496A	KAISER	LINDELL	R.R. 2, BOX 2096	FARMINGTON	09/19/88	A00042	80	50	0	D			09	36N	05E		430
81120A	JAKOUBEK	KURT	STAR RT BOX 254	VALLEY MINES	06/27/92	A00042	0	0	0	D	NE	NW	09	36N	05E		184
12465A	HINES	ANDY	RT. 2 BOX 48	FARMINGTON	03/07/89	B00026	80	35	0	D	SE	NE	10	36N	05E		327
40420A	WATKINS	RAY	RT 2 BOX 2028	FARMINGTON	01/02/90	A00042	80	20	0	D	NW	SW	10	36N	05E		246

ID	Name	First Name	Address	City	Date	Permit		GPM	SWL						Depth
0A	WADE	DON	R R 3 BOX 3890	FARMINGTON	05/14/88	A00042	80	15	50 D	NE	NE	32	36N	06E	184
2714A	O'SULLIVAN	JOHN	P.O.BOX 905	FARMINGTON	02/10/87	B00026	80	10	70 D	SW	NE	32	36N	06E	184
03445A	O'SULLIVAN	ERIC	RT. 3 BOX 321-B	FARMINGTON	12/25/87	A00042	80	12	50 D	SE		32	36N	06E	145
0391A	WADE	DAN	RT 3 BOX 3882	FARMINGTON	10/31/89	A00042	80	20	60 D	NE	NE	32	36N	06E	184
4976A	HUGHES	THOMAS O	ROUTE 3	FARMINGTON	02/21/90	A00049	103	100	40 D	NW	SE	32	36N	06E	147
53644A	MINKEL	LLOYD E.	RT. 3, BOX 3940	FARMINGTON	09/28/90	A00033	80	17	118 D	NW	SE	32	36N	06E	140
51733A	MINKEL	LARRY	RT 3 BOX 3937	FARMINGTON	07/31/91	A00033	80	12	20 D	NW	SE	32	36N	06E	140
55165A	KOPPEIS	MIKE	827 BELL DRIVE	FARINGTON	09/24/91	A00042	80	30	60 D	NE	NE	32	36N	06E	184
11187A	COLEMAN	ARRON			12/21/88	B00236	80	30	0 D	SW	SW	33	36N	06E	287
43548A	MCGUIRE	DENNIS	RT 3	FARMINGTON	11/04/89	C00052	0	0	30	NE	NW	33	36N	06E	0
44968A	O'SULLIVAN	KEVIN	RT 3 BOX 3911	FARMINGTON	01/15/90	A00049	82	15	81 D	NE	NE	33	36N	06E	187
44254A	BIBLE	BRUCE	RT. 3, BOX 3776	FARMINGTON	08/30/89	A00042	60	20	0 D	SE	NE	34	36N	06E	123
37552A	BAYLESS	EMMA LEE	RT 3 BOX 3784	FARMINGTON	06/30/92	A00042	0	0	0 D	SE	NE	34	36N	06E	225
51598A	TUMULTY	KATHLEEN	RT. 3, BOX 3785	FARMINGTON	06/15/92	A00049	82	30	52 D	NW	SW	35	36N	06E	165
77571A	CARTER	BRIAN K	RT 3 BOX 3789	FARMINGTON	08/27/92	A00049	0	0	0 D	SE	NW	35	36N	06E	189
07720A	BEISHIR	TED J.	5423 S. LINDBERG	ST. LOUIS	06/13/88	B00205	80	6	40 D	NE	SE	36	36N	06E	400
31016A	HOOSE	RAYMOND	RT 3 BOX 5319	FARMINGTON	06/23/89	A00042	80	12	0 D	NE	NE	36	36N	06E	123
37958A	BEISHIR	TED J	BLOOM RD	f RARMINGTON	06/13/88	A00220	0	0	0 H	NE	SE	36	36N	06E	0
32803A	GORE	HENRY	R R 3 BOX 3705	FARMINGTON	09/28/89	A00042	80	20	45 D	SE	SW	36	36N	06E	164
06067A	MCCRORY	STAN	14 ASH STREET	? ✓BONNE TERRE	02/10/88	A00042	80	25	250 D			—	37N	04E	553
43090A	STEGALL	NORMAN	RT. 4, BOX 115	? ✓BONNE TERRE	12/12/89	A00042	80	25	100 D			—	37N	04E	328
43118A	POWERS	JOHN	RT. 5, BOX 1090	? ✓BONNE TERRE	07/26/90	A00042	80	20	32 D	NW	SE	—	37N	04E	64
55099A	CROSS	MICHAEL D	P O BOX 1573	? ✓DESLOGE	05/09/91	A00332	80	60	30 D	SE	NE	—	37N	04E	284
67854A	MUSE	EUGENE	RT 3	yes ✓BONNE TERRE	12/26/91	A00332	80	7	80 O	NW	SW	—	37N	04E	304
11415A	RICHARDSON	DWIGHT	P.O. BOX 124	FLAT RIVER 1	12/02/87	C00067	81	25	81	SW	SE	01	37N	04E	144
08255A	NASH	CARL	RT. 4, BOX 344	yes ✓BONNE TERRE, 2	01/14/88	A00042	80	20	0 D	SE	NW	01	37N	04E	143
10235A	NASH	CARL	802 MONROE	FLAT RIVER 3	04/29/88	C00064	0	0	0 D			01	37N	04E	0
11409A	MARTIN	JERRY	RT. 4, BOX 301-G	yes ✓BONNE TERRE 4	01/20/88	A00042	80	8	0 D	SE	SW	02	37N	04E	300
12292A	NICKELSON	MARTY	RT 4 BOX 303C	yes ✓BONNE TERRE 5	02/01/89	A00040	80	27	135 D			02	37N	04E	400
01041A	CARTER	IVAN	2324 LORRAINE	CAHOKIA 6	07/22/87	A00033	80	20	200 D			02	37N	04E	320
42572A	NICKELSON	MARTY	RT 4 BOX 3030	yes ✓BONNE TERRE 7	09/17/90	A00332	160	30	40	SE	NE	02	37N	04E	204
86574A	LINDSEY	RAY	PO BOX 346	yes ✓BONNE TERRE 8	06/16/92	A00332	0	0	0 D	SW	NE	02	37N	04E	210
02998A	KUEHNER	TOM	RT 2	yes ✓BONNE TERRE 9	08/18/87	A00042	80	30	0 D	NE	NW	03	37N	04E	485
04223A	KUENER	TOM	RT. 2	✓BONNE TERRE	08/26/87	A00031	0	0	0 D	NE	NW	03	37N	04E	0
15074A	HARRIS	DONALD	RT 4 BOX 2818	✓BONNE TERRE	05/05/89	B00236	80	15	0 D	SE	SE	04	37N	04E	410
42635A	CAIN	PAUL & VICKY	RT 4	✓BONNE TERRE	08/03/92	A00141	0	0	0	SE	SW	04	37N	04E	220
04481A	KASSABAUM	FRED	P.O. BOX 255	no ✓BONNE TERRE	08/19/87	A00042	80	12	0 D	NE	SE	07	37N	04E	369
31071A	GRIFFIN	IVAN	C/O MARVIN GRIFFIN	no ✓BONNE TERRE	07/11/89	A00040	80	35	240	SW	NW	07	37N	04E	375
42395A	DAUGHERTY, JR.	RICHARD	412-D STREET	✓BONNE TERRE 4	02/16/90	A00042	80	18	0 D	NW	SW	09	37N	04E	34[illegible]
47062A	RICKARD	TERRY	602 CHESTNUT	✓DESLOGE	08/19/90	A00040	80	34	210	SW	NE	09	37N	04E	3
61549A	VAN VOARHEES	MARY	RT 3 BOX 153	DESOTO	02/21/92	A00049	82	6	77 D	NE	NW	09	37N	04E	
86569A	CLAYWELL	MARK	433 N. ALLEN	✓BONNE TERRE	06/09/92	A00332	80	60	150	SE	SW	09	37N	04E	
11401A	CARROW	ZENO C.	RT. 4, BOX 103-A	✓BONNE TERRE 10	05/13/88	A00042	80	20	0 D	NE	SW	10	37N	04E	[illegible]
42406A	MULLINS	DAVID		✓BONNE TERRE 11	01/15/90	A00042	80	25	0 D	SW	SW	10	37N	04E	45[illegible]
60015A	SMITH	WENDELL	RT 4 BOX 102	✓BONNE TERRE 12	05/21/91	A00042	80	20	60 D	SE	SW	10	37N	04E	4[illegible]

[illegible]A	BARTON	STEVE	RT 4 BOX 101C	BONNE TERRE #13	09/28/91	A00042	80	12	60	D	SE	SW	10	37N	04E	223
[illegible]577A	HAMBRICK	DWIGHT	315 7TH STREET	FARMINGTON 14	04/24/89	A00042	80	20	60	D	SW	NE	11	37N	04E	205
43080A	MAGURA	KENNY	RT. 1, BOX 339	BONNE TERRE #15	08/25/89	A00042	80	20	70	D	NW	NW	11	37N	04E	205
43121A	GIBSON	DAVID	RR 4 BOX 521A	BONNE TERRE 16	07/10/90	A00042	80	30	0	D	NW	NW	11	37N	04E	164
53791A	HAMPTON	HARVEL	RT. 4, BOX 347	BONNE TERRE 17	08/17/90	A00042	80	60	100	D			12	37N	04E	430
15724A	HOME SERVICE OIL		6918 FRONT STREET	BARNHART #18	08/21/89	A00049	82	45	140	D	SE	NW	13	37N	04E	413
67853A	STACY	ALICE	RT 3 BOX 41-M	BONNE TERRE #19	12/23/91	A00332	80	30	50	D	SW	NW	14	37N	04E	204
67852A	MABERY	DENNIS	RT 3 BOX 41P	BONNE TERRE #20	12/20/91	A00332	80	60	60	D	SW	NW	14	37N	04E	384
86568A	MARLER	RONALD	RT. 3, BOX 24	BONNE TERRE #21	06/08/92	A00332	80	20	180		NW	SW	14	37N	04E	310
55181A	RADFORD	EDWARD	RT 3 BOX 55R	BONNE TERRE #22	/ /	A00042	80	18	80	D	NE	NW	15	37N	04E	328
65181A	MESEY	THOMAS	RT 3	BONNE TERRE #23	01/02/92	A00042	80	25	110	D	SW	NE	15	37N	04E	307
11418A	SMITH	WES	RT. 3, BOX 62 D	BONNE TERRE	06/04/88	A00042	80	6	140	D	SE	NW	16	37N	04E	451
42580A	DORSETT	ANTHONY	1366 RUERIVIA	BONNE TERRE	10/23/90	A00332	80	10	120		NW	NE	16	37N	04E	304
61394A	HAMANN	GLADYS	RT 4 BOX 114A	BONNE TERRE	05/10/91	A00049	82	25	215	D	NW	NW	16	37N	04E	392
00923A	AUBUCHON	BRIAN	RT 4	BONNE TERRE	05/12/87	A00042	80	10	0	D	NE	NW	17	37N	04E	123
00924A	AUBUCHON	BRIAN	RT 4	BONNE TERRE	06/16/87	A00031	0	0	0	D	NE	NW	17	37N	04E	123
61695A	WEIBHE	EDWARD	558 CAPRI DRIVE	BONNE TERRE	05/01/91	A00033	80	12	120				17	37N	04E	500
12595A	WILKINSON	JILL	RT. 3 BOX 10C	BONNE TERRE #24	03/03/89	A00042	80	20	200	D			24	37N	04E	348
15672A	WILKINSON	JILL	RT. 3, BOX 10-C	BONNE TERRE #25	03/03/89	A00042	80	20	200	D			24	37N	04E	348
49393A	BACH	JOHN F.	LAKEWOOD SUBDIVISION	BONNE TERRE #26	06/21/90	A00049	82	20	163	D	NW	SE	24	37N	04E	312
67873A	MCGEE	MARGIE	RT 1 BOX 60	MINERAL POINT	03/06/92	A00332	80	6	160		NW	SW	31	37N	04E	464
86584A	MOSIER	LARRY	RT 33 BOX 174	FLAT RIVER	07/31/92	A00332	0	0	0	D	NE	NW	31	37N	04E	390
02027A	BARNETT	MIKE	ROUTE 33	FLAT RIVER	07/30/87	B00026	80	40	0	D			33	37N	04E	184
02995A	LYNCH	CLAUDE	1200 PINE	LEADWOOD	10/06/87	A00042	80	20	90	D	SE	SE	33	37N	04E	166
03487A	BARNETT	MIKE	RT. 33, BOX 47	FLAT RIVER	11/26/87	C00064	0	0	70	D			33	37N	04E	0
11181A	BARNETT	MIKE	RT. 33, BOX 47	FLAT RIVER	08/30/88	A00042	80	15	0	D			33	37N	04E	184
63106A	VALNER	BRUCE	RT 2 BOX 248	POTOSI	09/21/91	A00040	80	24	90		NE	SE	33	37N	04E	365
01583A	STEWART	JOE	613 BANK	LEADWOOD	07/17/87	B00026	81	5	0	D	SW	NW	34	37N	04E	246
02782A	STEWART	JOE	613 BANK STREET	LEADWOOD	/ /	C00064	0	0	0		SW	NW	34	37N	04E	0
56571A	SLOAN	BRAD	112 S 5TH ST	DESLOGE	11/20/90	A00049	82	30	56	D	SW	NE	36	37N	04E	433
81133A	B&G SIGN COMPANY		RT 2 BOX 129F	BONNE TERRE	04/23/92	A00042	80	20	20	D			SN	37N	04E	225
68316A	CHRISTOPHER	CARSON	RT. 3, BOX 30	FLAT RIVER	07/03/92	A00033	80	17	50	D			SN	37N	04E	360
11177A	USINA	LEE	4601V GEMINI,	ST. LOUIS,	12/07/88	A00042	80	30	100	D				37N	05E	287
11184A	PEPPERS	DALE	RT 1 BOX 538	BONNE TERRE,	07/01/88	A00042	80	30	0	D	NW	NW		37N	05E	287
11422A	WINCH	JOE	RT. 2, BOX 293	BONNE TERRE	06/09/88	A00042	80	25	80	D				37N	05E	287
12591A	BECKER	JAMES	RT. 1 BOX 347F	BONNE TERRE	01/13/89	A00042	80	35	40	D				37N	05E	307
02777A	RASNIC	JEFF	RT 2, BOX 119	BONNETERRE	/ /	C00067	0	0	0		SW	SE		37N	05E	0
03411A	HUGHES	RICHARD	RT.4 BOX 5 BIG RIVER HILLS	BONNE TERRE	07/30/87	B00026	80	30	185	D				37N	05E	348
03441A	BESS	RALPH	RR1 BOX 385	BONNE TERRE	03/12/87	B00026	80	100	0	D	SE	NW		37N	05E	287
04477A	MCDOWELL	SCOTT	RT. 2 BOX 2595	FARMINGTON	08/31/87	A00042	80	30	0	D				37N	05E	270
04711A	PERRYMAN	JIM	1305 A EAST CHESTNUT	DESLOGE	12/04/87	A00042	80	40	50	D				37N	05E	294
06068A	LONG	JOHN	1009 OLD BONNE TERRE RD.	DESLOGE	03/09/87	A00042	80	20	60	D	SE	SE		37N	05E	347
06355A	KASSEBAUM	JOAN	RT. 2	BONNETERRE	03/15/88	A00031	0	0	4	D				37N	05E	123
08208A	RICE	JAMES	RT. 2 BOX 122 N	BONNE TERRE	07/18/88	A00042	80	20	20	D				37N	05E	[illegible]
08533A	WYATT	ROY	RT. 2, BOX 129	BONNE TERRE,	07/06/88	A00042	81	20	80	D				37N	05E	[illegible]

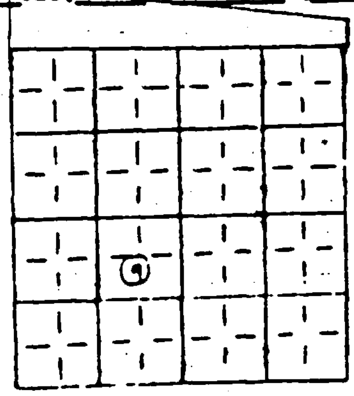
[illegible]0A MARLER	TOM	ROUTE 2, BOX 124	BONNETERRE	07/28/87	C00064	0	0	0				37N 05E	0
[illegible]0511A JENKINS	BILL	RT 4 BOX 29	BONNE TERRE	10/18/88	A00042	80	30	40 D				37N 05E	143
10412A PAYNE	DAVID & BARBARA	HILLSBORO RD.	BONNE TERRE	05/25/88	A00033	80	0	201 D				37N 05E	240
43765A WIGGER	L.C.	RT 1 BOX 397	BONNE TERRE	11/07/89	A00033	80	18	200 D				37N 05E	220
44265A RICE	JIM	ROTUE 2 BOX 122-N	BONNE TERRE	09/29/89	A00042	80	0	40 D				37N 05E	143
43770A GREER	GARY	RT 1 BOX 347	BONNE TERRE	01/29/90	A00033	80	20	170 D				37N 05E	220
40382A BURR	KAREN	RT 2 BOX 404	BONNE TERRE	10/20/89	A00042	80	25	0 D				37N 05E	289
43758A SPRENGEL	RICHARD	2807 STATE STREET	CHESTER	10/30/89	A00033	80	15	220				37N 05E	280
31508A LEFTRIDGE	WILMA	RT 1 BOX 356	BONNE TERRIE	09/05/85	A00332	80	30	60 D	SW	SE		37N 05E	229
42383A HARRIS	JOHN M.	RT. 2, BOX 135-R	BONNE TERRE	04/11/90	A00042	149	30	70 D				37N 05E	289
41898A LARKIN	LARRY	RR 2, CONWAY ROAD	FARMINGTON	09/13/88	A00033	80	15	220 D				37N 05E	345
42534A STABENOW	GARY	420 N. ALLEN	BONNE TERRE	05/25/90	A00332	82	60	24 D	SW	SW		37N 05E	204
43083A WEITZEL	DON	P.O. BOX 105	FLAT RIVER	11/30/89	A00042	80	20	0 D				37N 05E	287
53772A WINCH	ROGER	RT. 2, BOX 2946	BONNE TERRE	07/18/90	A00042	80	40	90 D				37N 05E	287
43097A SIKES	FRED	RT. 1, BOX 412-N	BONNE TERRE	06/01/90	A00042	80	25	80 D	SE	NW		37N 05E	246
43117A OWEN	KEN	RT 4 BOX 38	BONNE TERRE	06/18/90	A00042	80	40	0 D				37N 05E	368
53827A REDMOND	JIM	P.O. BOX 125	BONNE TERRE	09/22/90	A00042	80	20	15 D				37N 05E	205
53801A WELLS	CHARLES	P.O. BOX 462	BONNE TERRE	08/23/90	A00042	80	20	0 D				37N 05E	243
53799A HOUSE	MILBORN	RT. 2	BONNE TERRE	08/22/90	A00042	80	20	0 D				37N 05E	243
53822A MEYER	DONALD	RT 2 BOX 122 N-3	BONNE TERRE	09/11/90	A00042	80	20	40 D				37N 05E	164
53821A GAUGEL	DENNIS	118 PARK	BONNE TERRE	09/11/90	A00042	80	40	0 D				37N 05E	307
53836A GOVEREAU	OSCAR	RT 2 BOX 171	BONNE TERRE	10/16/90	A00042	80	30	60 D	SE	SW		37N 05E	164
53838A LAYNE	RICHARD		BONNE TERRE	11/16/90	A00042	80	50	80 D				37N 05E	389
10504A UPCHURCH	LARRY	705 E WALNUT ST	DESLOGE	08/24/88	A00042	80	25	20 D				37N 05E	307
60018A GRUAHLA	MIKE	BOX 1511	DESLOGE	06/14/91	A00042	80	30	0 D				37N 05E	184
60019A SCOTT	RICHARD	601 S CANTWELL LANE	DESLOGE	06/12/91	A00042	80	30	0 D	SW	SW		37N 05E	220
55109A LINDSEY	HOMER E	RT 1 BOX 226	BONNE TERRE	06/24/91	A00332	80	30	40 D	SW	SE		37N 05E	164
55111A SISK	DAVID	RT 1 BOX 340	BONNE TERRE	07/05/91	A00332	80	30	30 D	NW	NE		37N 05E	104
65111A WINCH	ROGER	RT 2 BOX 294G	BONNE TERRE	07/03/91	A00042	80	40	100 D				37N 05E	307
67831A RUDD	JAMES	8745 FLORENCE	ST LOUIS	08/13/91	A00332	80	30	60 D	NE	SE		37N 05E	264
65138A BLACK	DAMON	RT 1	BONNE TERRE	08/24/91	A00042	80	40	70 D				37N 05E	287
65179A WOOD	J D	RT 1 BOX 412C	BONNE TERRE	12/31/91	A00042	80	50	60 D				37N 05E	290
84683A SUNRISE BAPTIST		P O BOX 472	BONNE TERRE	04/02/92	A00042	80	12	38 D				37N 05E	205
87547A MAYNARD	MICHAEL	RT 4 BOX 49	BONNE TERRE	07/21/92	A00042	0	0	0 D				37N 05E	328
87576A BECKER	JIM	RT 4 BOX 42	BONNE TERRE	09/23/92	A00042	0	0	0 D				37N 05E	164
01745A BANDERA	BEVERLY	RT 1 BOX 72	BONNE TERRE	03/07/87	A00042	100	0	0 D	NE	NW	04	37N 05E	300
04071A BANDERA	ANGELO	105 N. DIVISION	BONNE TERRE	06/30/87	A00042	104	285	90 D	NE	NW	04	37N 05E	285
06578A FANGER	DAN	RR	BONNE TERRE	04/09/88	A00033	82	25	100 D			04	37N 05E	300
34140A FARRAR	TIM	R R 1 BOX 791	STEELVILLE	02/02/90	A00133	0	0	0			04	37N 05E	252
87540A THAXTON	BILLY	1231 SUMMER POINT	FENTON 27	09/16/92	A00042	0	0	0 D			05	37N 05E	164
06593A LASLEY	VERNON	RT 1 BOX 57-A	BONNE TERRE 28	05/13/88	A00082	80	15	50 D			06	37N 05E	271
08945A RAWSON	KEITH	807 E. CHESTNUT	DESLOGE 29	08/31/88	A00049	82	75	77 D	NW	NE	06	37N 05E	352
43126A JENKERSON	TERRY	219 STONE	BONNE TERRE 30	06/19/90	A00042	80	40	0 D			06	37N 05E	369
65174A COOK	MIKE	610A CHERRY ST.	BONNE TERRE 31	/ /		80	25	0 D	SW	SW	06	37N 05E	348
04708A JOHNSON	HOWARD	P.O. BOX 292	32	01/16/88	A00042	80	10	20 D			07	37N 05E	143

EBBINGHAUS	RICK	RT. 1, BOX 401	BONNE TERRE, ~~29~~ 33	07/13/88	A00042	80	40	45 D			07	37N	05E	340
117A HUBBARD	RANDY	10 JANE STREET	BONNE TERRE ~~30~~ 34	03/28/90	A00042	80	25	0	NE	SE	07	37N	05E	210
116A WHITIER	RON	419 ADAMS	DESLOGE ~~31~~ 35	06/19/90	A00042	80	30	0 D		NE	07	37N	05E	164
386A BREWEN	BRIAN	RT. 4	BONNE TERRE ~~32~~ 36	10/25/89	A00042	80	5	0 D			07	37N	05E	328
2571A PARKS	TOM	RT 4	BONNE TERRE ~~33~~ 37	09/13/90	A00332	80	20	40	NW	NE	07	37N	05E	164
427A COMPTON	TRUDY	RT 1 BOX 370	BONNE TERRE ~~34~~ 38	08/15/90	A00049	82	60	72 D	SE	NW	07	37N	05E	312
1145A DAY	ROMAN D.	RT 4 BOX 48	BONNE TERRE ~~35~~ 39	05/22/92	A00042	80	50	60 D	SE	NE	07	37N	05E	348
3177A PAGE	KEN	RT 1 BOX 334	BONNE TERRE	08/20/87	B00028	82	12	40 D	SW	SE	10	37N	05E	127
3178A PAGE	KEN	RT 1 BOX 334	BONNE TERRE	08/20/87	A00059	0	0	0	SW	SE	10	37N	05E	127
1615A DECKER	RICHARD	RT 1 BOX 245E	BONNE TERRE	06/29/92	A00049	0	0	0 D	SW	SW	10	37N	05E	267
3285A JAYCOX	DAVID	P.O. BOX 822	STEELVILLE	07/29/89	A00221	293	30	185	NW	NE	13	37N	05E	330
0292A BASLER	WILLIAM	BOX 122 RT 2	BONNE TERRE	03/06/87	A00049	82	25	50 D	NE	NW	14	37N	05E	316
1412A PETERSON	JOHN	RT. 1, BOX 323 A	BONNE TERRE	07/14/87	A00042	80	25	70 D		SE	15	37N	05E	123
5886A KASSABAUM	JOANN	RT. 2	BONNE TERRE	03/15/88	A00042	80	0	4 D			16	37N	05E	123
27979A BROWN	DONNIE	RT 2 BOX 1368	BONNIE TERRE	12/05/89	C00212	0	0	40 D	SW	SE	20	37N	05E	260
53643A GOODMAN	JERRY & SILVIA	RT. 2, BOX 284-X	BONNE TERRE	09/26/90	A00033	80	17	230 D			20	37N	05E	260
40389A COOK	DAVE	RR 1 BOX 250E	BONNE TERRE	10/26/89	A00042	80	35	65 D	NW		22	37N	05E	266
42566A FARFARCE	ANGLO	RT. 1, BOX 323	BONNE TERRE	08/22/90	A00332	80	20	80	NW	SE	22	37N	05E	244
41977A FITZGERALD	DANIEL	GREEN ACRE TRAILER PK	ESTHER	10/02/90	A00033	80	19	175 D	NE	SE	22	37N	05E	220
59986A DUNCAN	JOHN	1825 QUAIL RUN	IMPERIAL	03/26/91	A00042	80	35	0 D	NE	SW	22	37N	05E	223
65127A MCGUIRK	JOSEPH	7352 FERNBROOK DR	ST LOUIS	07/26/91	A00042	80	18	30 D			22	37N	05E	143
77561A PRICE	JAMES&ELIZABETH	PO BOX 1604	DESLOGE	08/06/92	A00049	0	0	0 D	NE	SE	22	37N	05E	250
44264A HEBERLIE	THOMAS	ROUTE 3	FARMINGTON	09/28/89	A00042	80	15	455 D	NE	SE	23	37N	05E	143
40390A PATTERSON	GENE	STAR ROUTE	VALLE MINES	11/02/89	A00042	80	30	80 D			23	37N	05E	266
43096A WEIGLEITNER	SCOTT	#20 WOODLANE DR	BONNETERRE	06/14/90	A00042	80	20	0 D			23	37N	05E	269
49397A GRAY	BILL	RT. 1	BONNE TERRE	07/03/90	A00049	82	75	15 D	SE	SE	23	37N	05E	178
43122A BROWN	E. CARL	RT 2 BOX 2596A	FARMINGTON	07/11/90	A00042	80	20	90 D		NW	25	37N	05E	205
12604A JONES	KINCH	619 WEST MAIN STREET	FLAT RIVER	10/28/88	A00042	80	40	85 D			26	37N	05E	184
53775A MCDOWELL	DAN	RT. 1	BONNE TERRE	08/06/90	A00042	80	20	50 D	NE	NW	26	37N	05E	184
08294A KAISER	GREG	RT. 1, BOX 200	BONNE TERRE,	07/22/88	A00042	80	0	140 D	NW	SE	27	37N	05E	307
01288A GOVRO	JERRY	RT 2 BOX 172	BONNE TERRE	12/17/86	A00042	80	40	119 D			28	37N	05E	200
43099A BEARD	STEVE	RT. 2, BOX 302	BONNE TERRE	06/12/90	A00042	87	50	0 D			28	37N	05E	287
17304A UNDERWOOD	PEARL	404 W. FIRST ST.	FARMINGTON	09/24/87	A00042	80	15	34 D	NE	NE	28	37N	05E	170
61447A GOVREAU	JERRY	RT 2 BOX 172	BONNE TERRE	09/03/91	A00049	82	75	45 D	NW	SE	28	37N	05E	228
02993A MIDDLETON	LEMION	RT 2 BOX 324	BONNE TERRE	09/04/87	A00042	80	40	80 D			29	37N	05E	325
04462A BRANON	JIM	RT 2 BOX 121	BONNE TERRE	10/07/87	A00042	80	15	45 D			30	37N	05E	245
04689A MARLER	TOM	RT. 2, BOX 124	BONNE TERRE	06/20/87	B00026	80	30	0 D			30	37N	05E	123
15345A WAMPLER	RONNIE L.	RT. 2, BOX 270	BONNE TERRE	06/08/89	A00059	82	15	162 D	NW	NW	33	37N	05E	282
15386A HICKMAN	PAT		BONNE TERRE	06/06/89	B00255	80	35	265 D			S	37N	05E	385
11865A PATTERSON	JACK	127 L. DIVISION LT.	BONNE TERRE	02/06/89	A00040	80	45	105 D			SN	37N	05E	305
01289A BLACK	HOMER	100 W. FIRST & FITE	BONNE TERRE	01/28/87	A00042	80	50	90 D			SN	37N	05E	266
01348A RASNIC	JEFF	RT 2 BOX 119	BONNE TERRE	06/25/87	A00042	80	13	0 D	SE	SE	SN	37N	05E	143
02523A OLSON	NORMAN	RT 1 BOX 349	BONNE TERRE	10/03/87	A00042	150	25	82 D			SN	37N	05E	305
02989A RICE	JAMES	RT 2 BOX 122 N	BONNE TERRE	09/16/87	A00042	80	20	50 D			SN	37N	05E	143
03390A EAVES	ALLEN	RT 4 BOX 32	BONNE TERRE	08/06/87	A00042	80	20	44 D			SN	37N	05E	387

MISSOURI GEOLOGICAL SURVEY AND WATER RESOURCES, ROLLA, MISSOURI

SAMPLES REC'D 8-8-74 COUNTY ST. FRANCOIS MGS LOG NO. 27,653

DATE PROCESSED 11-15-74 THINS SENT ______ WELL NO. ______ SEC. 5 T. 36N R. 4E



OWNER Public Water Supply District # 2

ADDRESS ______

LOCATION ______

DRILLER D. Jennings, Jr.

CASING RECORD 424' of 11"

GROUTING RECORD 175 sacks cement

REMARKS ______

WELL COMPLETED 9-74 F.H.A. WELL ______ NO. SAMPLES 166 ELEVATION 920' Terry Schiling 7-20-77

GALLONS PER MINUTE ______ ACTION 5' TOTAL DEPTH 827'

S.W.L. 370' LOGGED BY Jack Wells TEMP.NO. 34

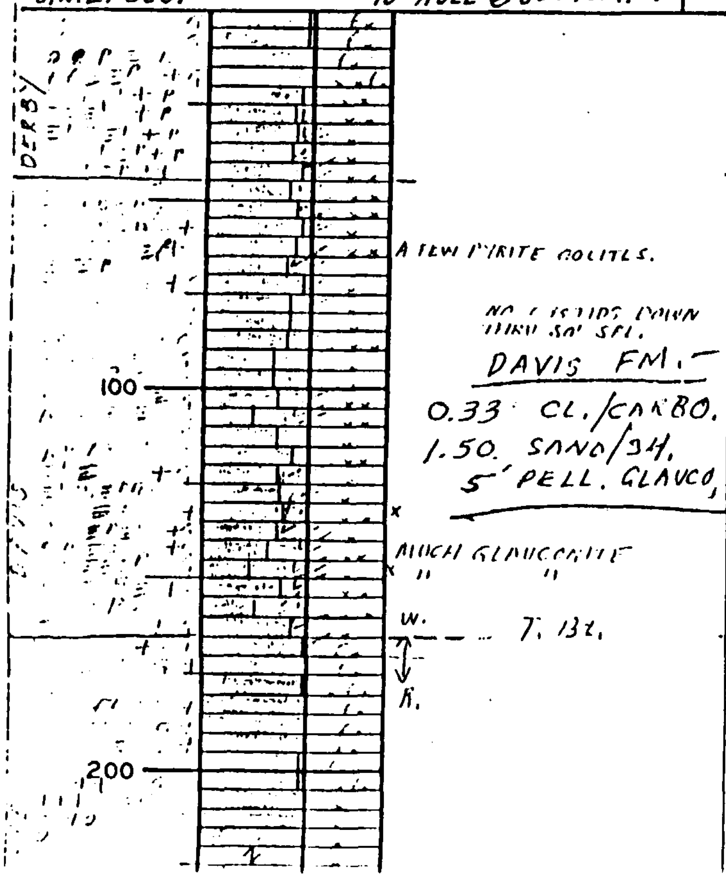
FORMATION	FROM (FT)	TO (FT)	FORMATION	FROM (FT)	TO (FT)
Derby-Doerun	0	90			
Davis	90	248			
Bonneterre	248	710?			
Lamotte	710?	827TD			

STATE OF MISSOURI (Bonneterre)
DIVISION OF
GEOLOGICAL SURVEY AND WATER RECOURCES

LOG NO.	OWNER	
23,002	LEAD BELT WATER CO.	
COUNTY	FARM 800' E. AND 1000' N. OF THE S.W. CORNER OF SECTION 13 - SURVEY 467.	WELL NO.
ST. FRANCOIS		
T 37 N. / R 4 E.	DRILLER BEN EMILY	
	DATE 7/24/64	
SURVEY 467 (13)	ELEV. 926	PROD. 375 G.P.M.
	LOGGED BY H.M. GROVES SEPT. 18, 1964	

INDEX SHEET NO.

REMARKS CSG: 535' of 10".
WATER: 525'.
530' of 14" HOLE; 190' of 10" HOLE.
S.W.L. 360'. 10" HOLE @ BOTTOM. ✓

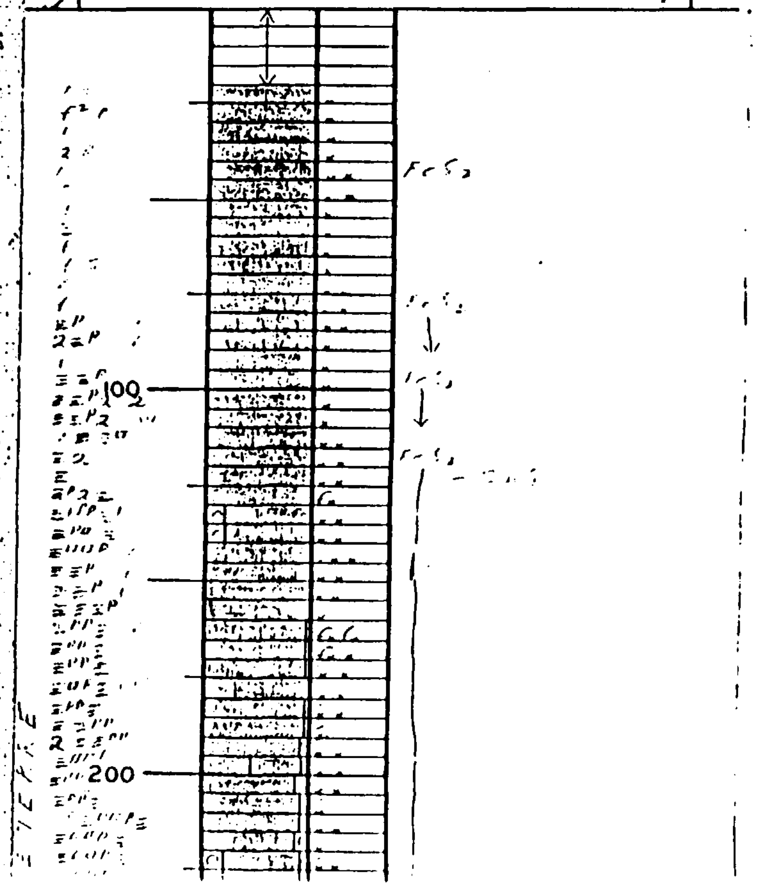


STATE OF MISSOURI
DIVISION OF
GEOLOGICAL SURVEY AND WATER RESOURCES

LOG NO.	OWNER	
26,280	LEAD BELT WATER CO.	
COUNTY	FARM IN DESLOGE (Flat River)	WELL NO. #1
ST. FRANCOIS		
T 37 N. / R 5 E.	DRILLER BEN EMILY	
	DATE	
(31)	ELEV. 808	PROD.
	LOGGED BY H.M. GROVES SEPT. 3, 1969	

REMARKS

SF-2



1992 EDITION

MISSOURI
CITY
&
COUNTY
MAPS

WELCOME TO:

ST. FRANCOIS COUNTY

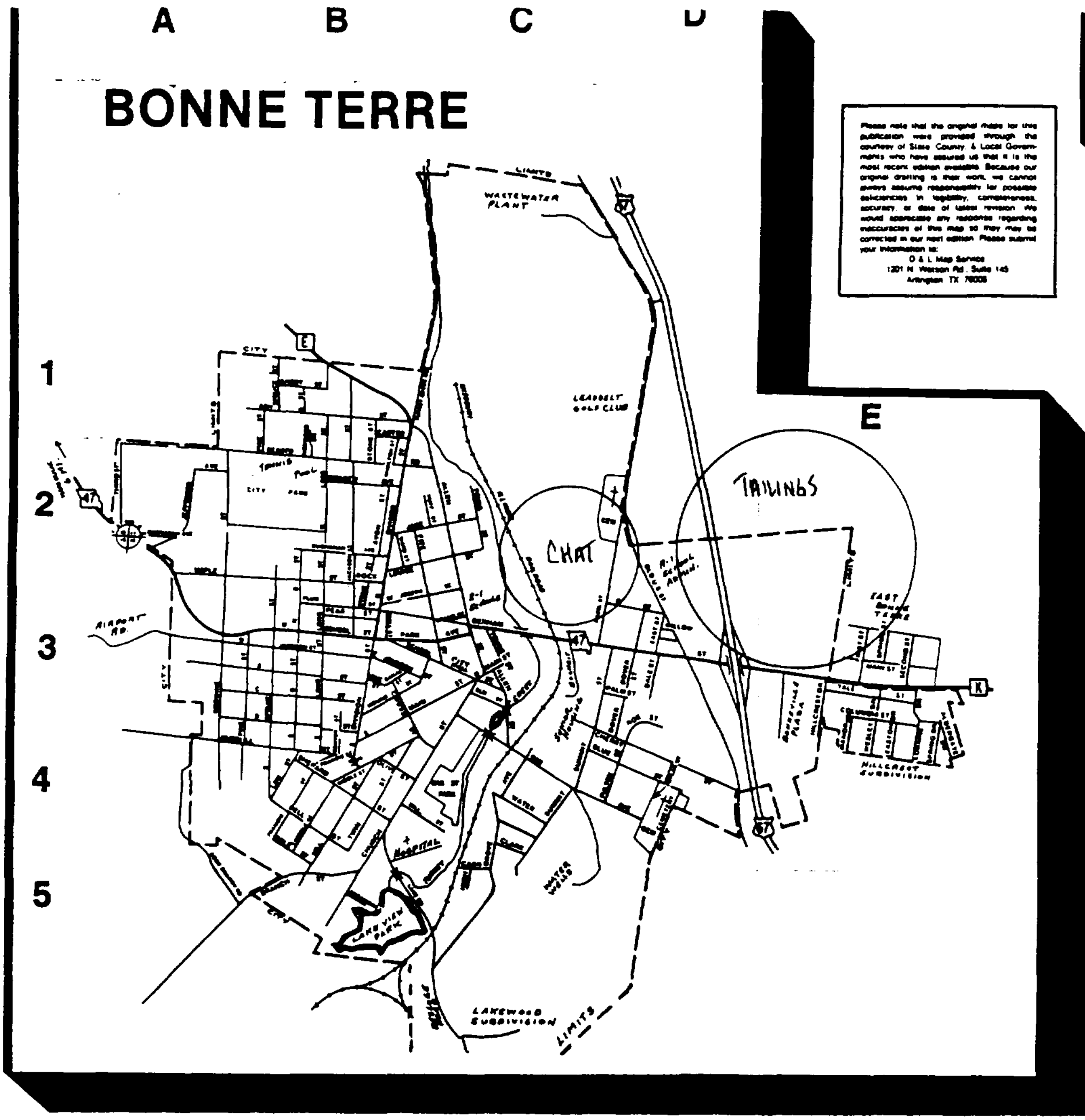
FEATURING CITIES OF

FARMINGTON, DESLOGE,
FLAT RIVER, & BONNE TERRE

PRESENTED BY

FARMINGTON CHAMBER OF COMMERCE

BONNE TERRE



Please note that the original maps for this publication were provided through the courtesy of State, County, & Local Governments who have assured us that it is the most recent edition available. Because our original drafting is their work, we cannot always assume responsibility for possible deficiencies in legibility, completeness, accuracy, or date of latest revision. We would appreciate any response regarding inaccuracies of this map so they may be corrected in our next edition. Please submit your information to:

D & L Map Service
1201 N. Watson Rd., Suite 145
Arlington, TX 76006

KEY TO MAP

ZONE DESIGNATIONS*

ZONE C

ZONE A

ZONE C

Base Flood Elevation Line with elevation in feet	~~513~~
Base Flood Elevation where uniform within zone	(EL 987)
Elevation Reference Mark	RM7x
River Mile	•M1.5

*EXPLANATION OF ZONE DESIGNATIONS

A flood insurance map displays the zone designations for a community according to areas of designated flood hazards. The zone designations used by FEMA are

ZONE	EXPLANATION
A	Areas of 100-year flood base flood elevations and flood hazard factors not determined
AO	Areas of 100-year shallow flooding where depths are between one (1) and three (3) feet, average depths of inundation are shown, but no flood hazard factors are determined
AH	Areas of 100-year shallow flooding where depths are between one (1) and three (3) feet, base flood elevations are shown, but no flood hazard factors are determined
A1-A30	Areas of 100-year flood, base flood elevations and flood hazard factors determined
A99	Areas of 100-year flood to be protected by flood protection system under construction, base flood elevations and flood hazard factors not determined
B	Areas between limits of the 100-year flood and 500-year flood, or certain areas subject to 100-year flooding with average depths less than one (1) foot or where the contributing drainage area is less than one square mile, or areas protected by levees from the base flood (Medium shading)
C	Areas of minimal flooding (No shading)
D	Areas of undetermined, but possible flood hazards
V	Areas of 100-year coastal flood with velocity (wave action), base flood elevations and flood hazard factors not determined
V1-V30	Areas of 100-year coastal flood with velocity (wave action), base flood elevations and flood hazard factors determined

NOTES TO USER

Certain areas not in the special flood hazard areas (zones A and V) may be protected by flood control structures.

This map is for flood insurance purposes only, it does not necessarily show all areas subject to flooding in the community or all planimetric features outside special flood hazard areas.

To determine if flood insurance is available in this community contact your insurance agent or call the National Flood Insurance Program at (800) 638-6620.

INITIAL IDENTIFICATION: MAY 31, 1974

FLOOD HAZARD BOUNDARY MAP REVISIONS: NOVEMBER 7, 1975

FLOOD INSURANCE RATE MAP EFFECTIVE: AUGUST 19, 1985

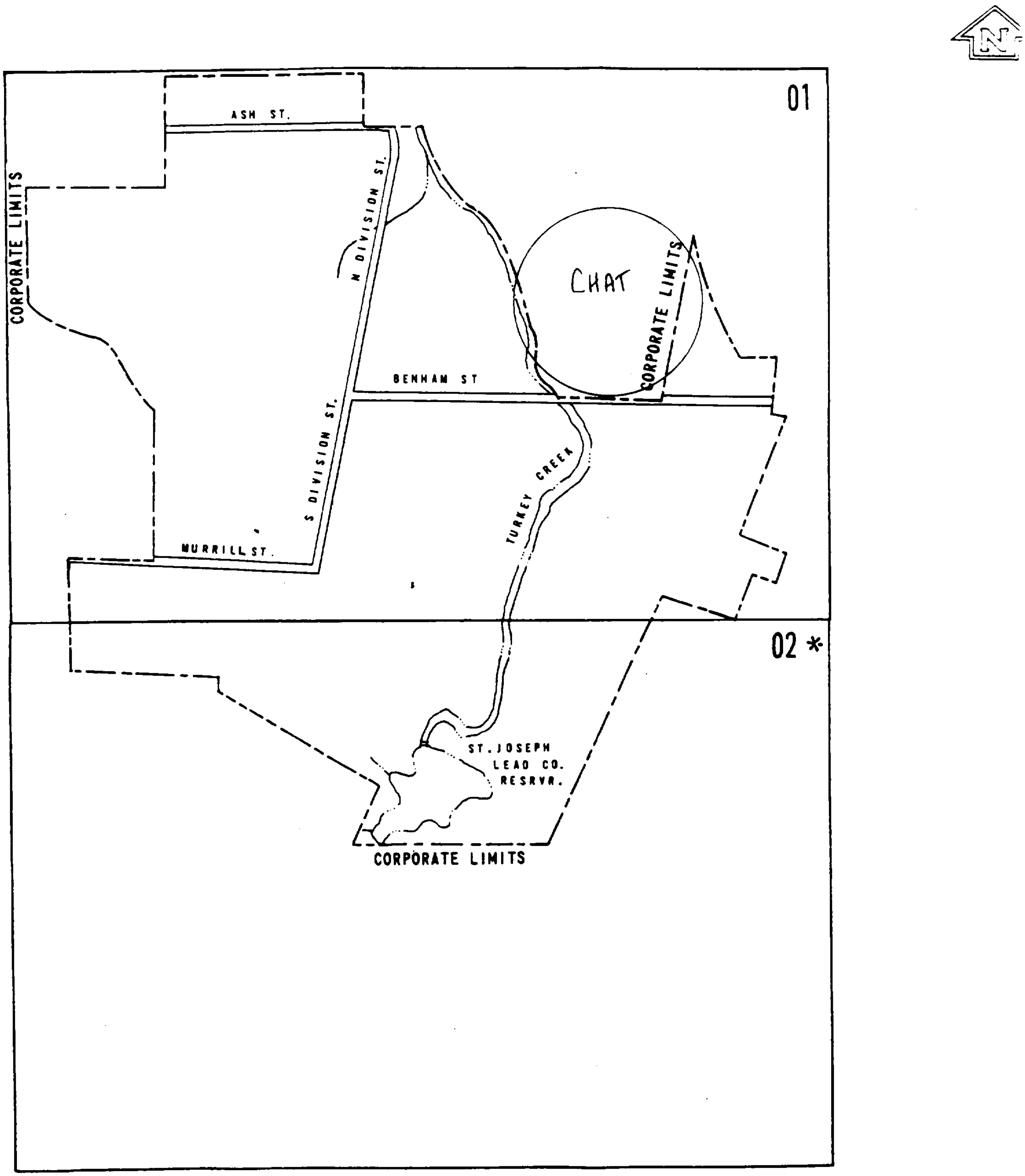
FLOOD INSURANCE RATE MAP REVISIONS:

FEDERAL EMERGENCY MANAGEMENT AGENCY

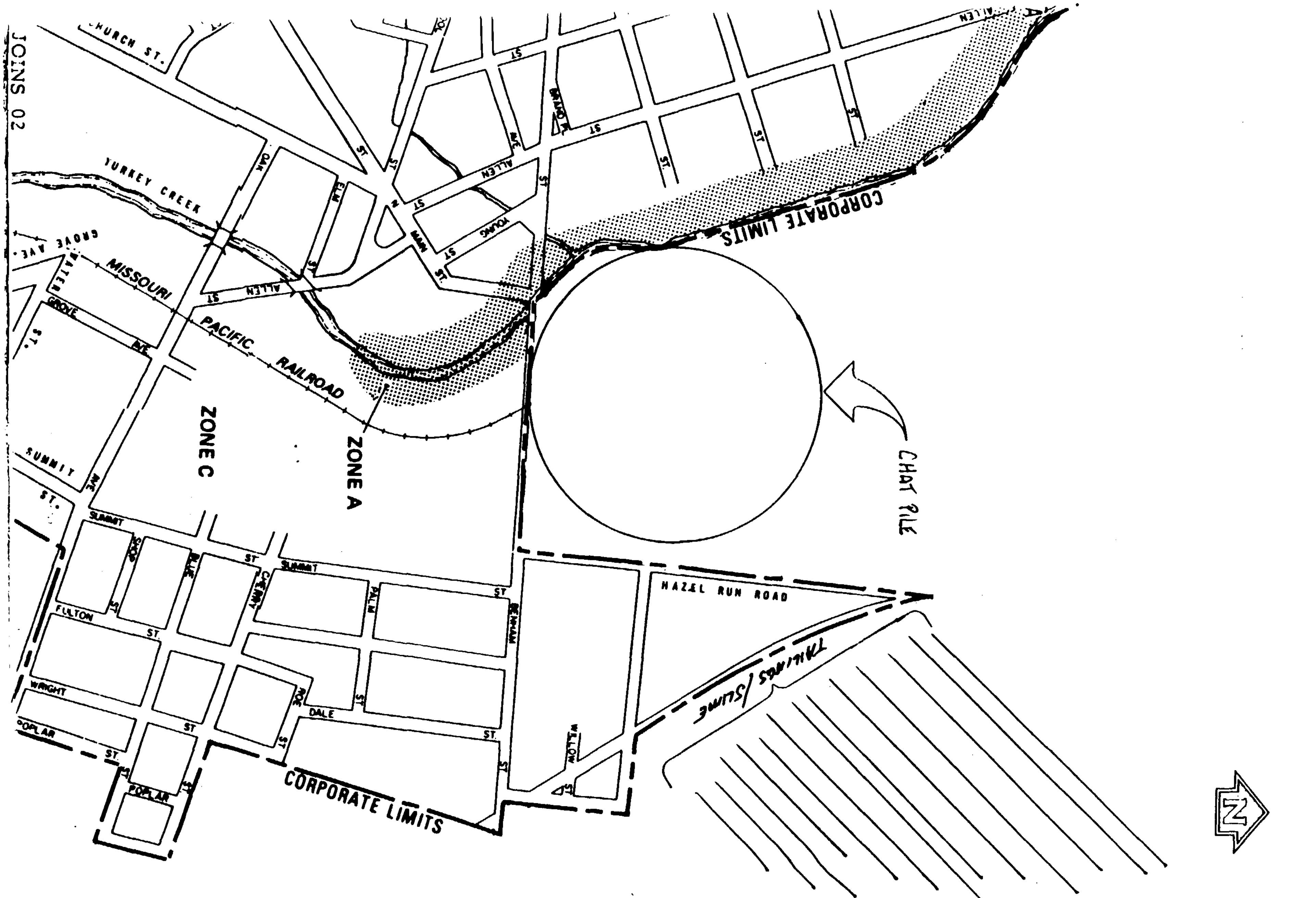
FIRM

FLOOD INSURANCE RATE MAP 01-02
MAP INDEX
CITY OF BONNE TERRE, MO
ST. FRANCOIS COUNTY

COMMUNITY NUMBER 290321 B



:D – AREA IN ZONE C



MAP 01

FEDERAL EMERGENCY MANAGEMENT AGENCY

CITY OF BONNE TERRE, MO

ST. FRANCOIS COUNTY

APPROXIMATE SCALE

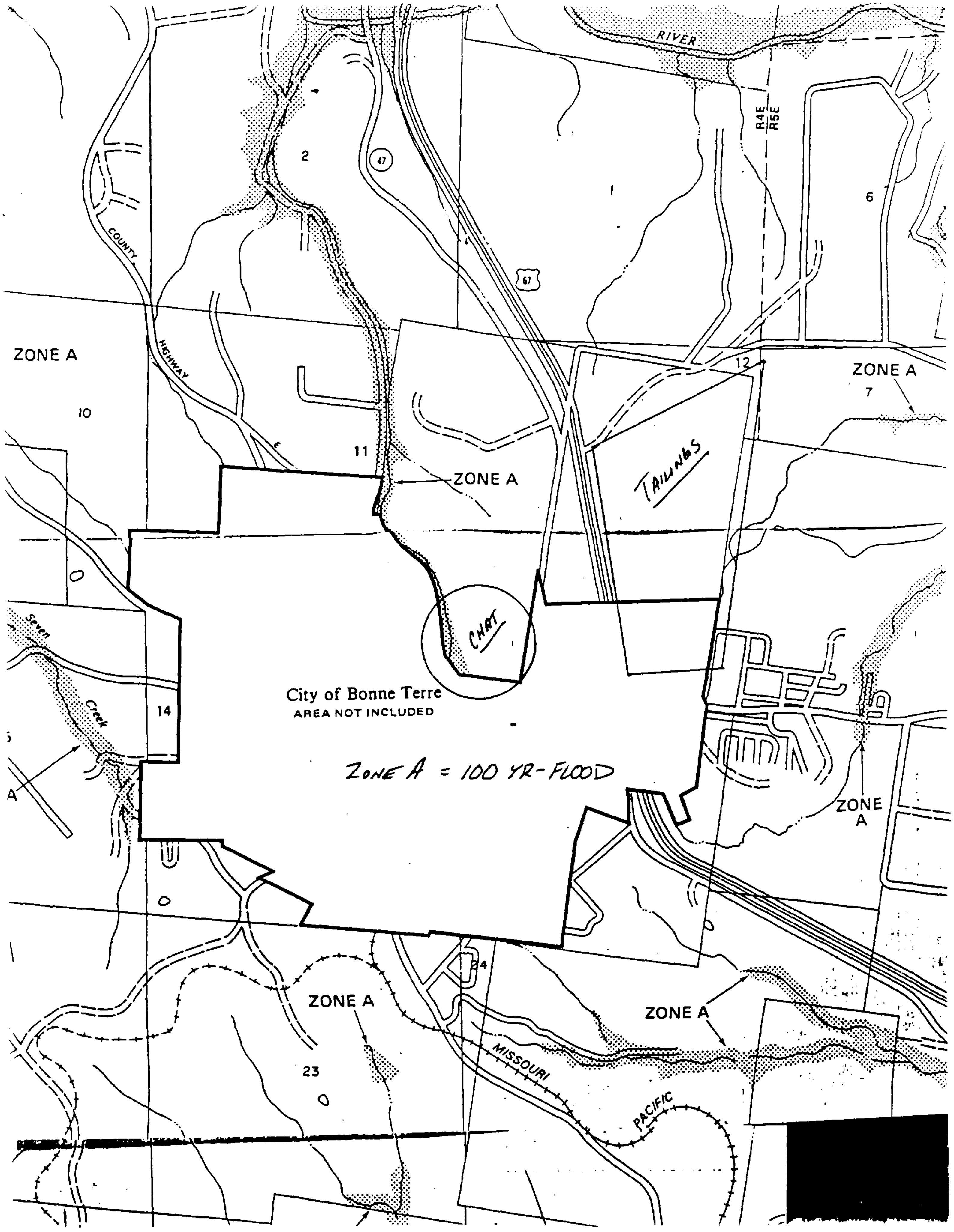
600 0 600 1200 1800 FEET

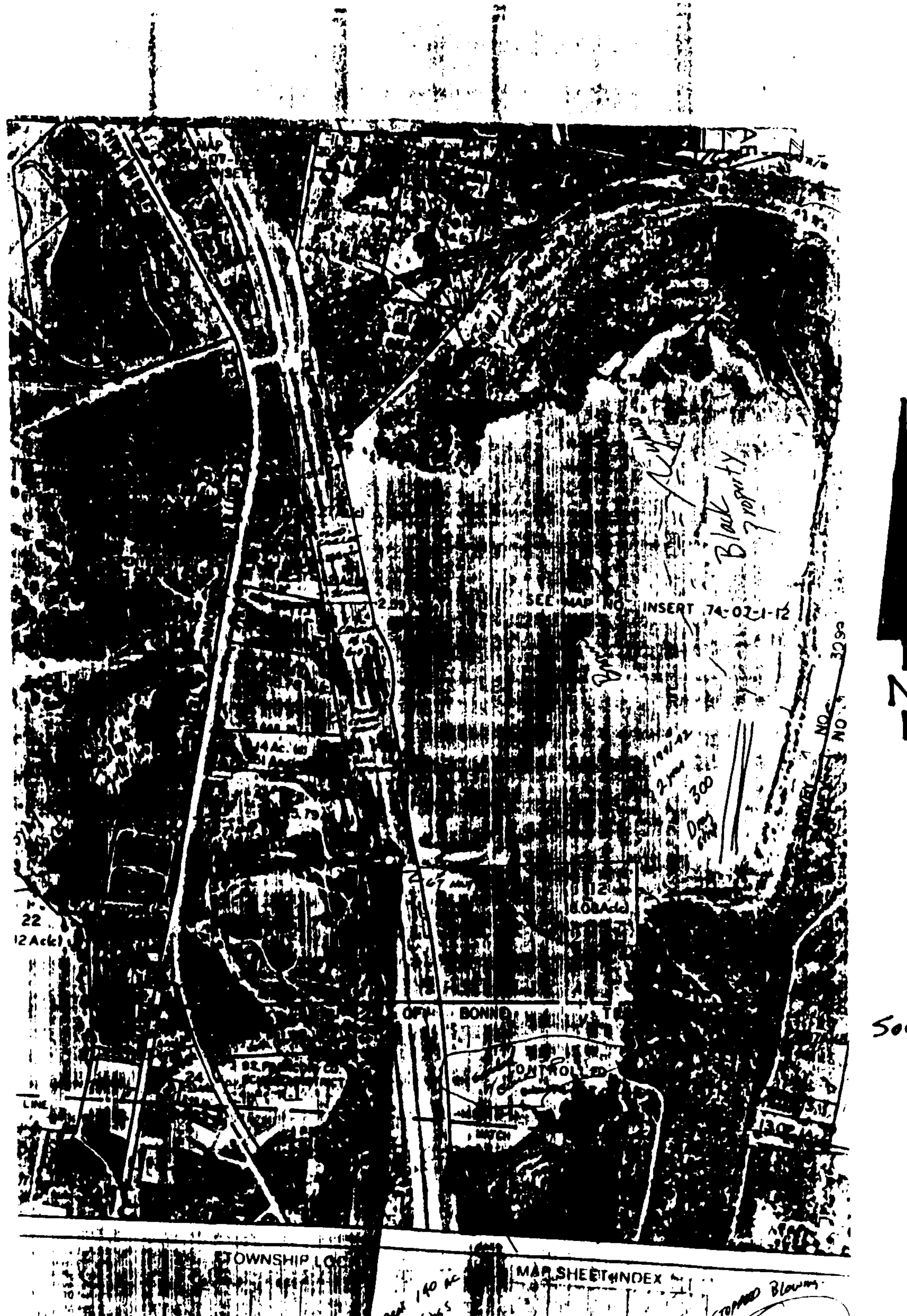
FLOOD INSURANCE RATE MAP

COMMUNITY NUMBER 290321

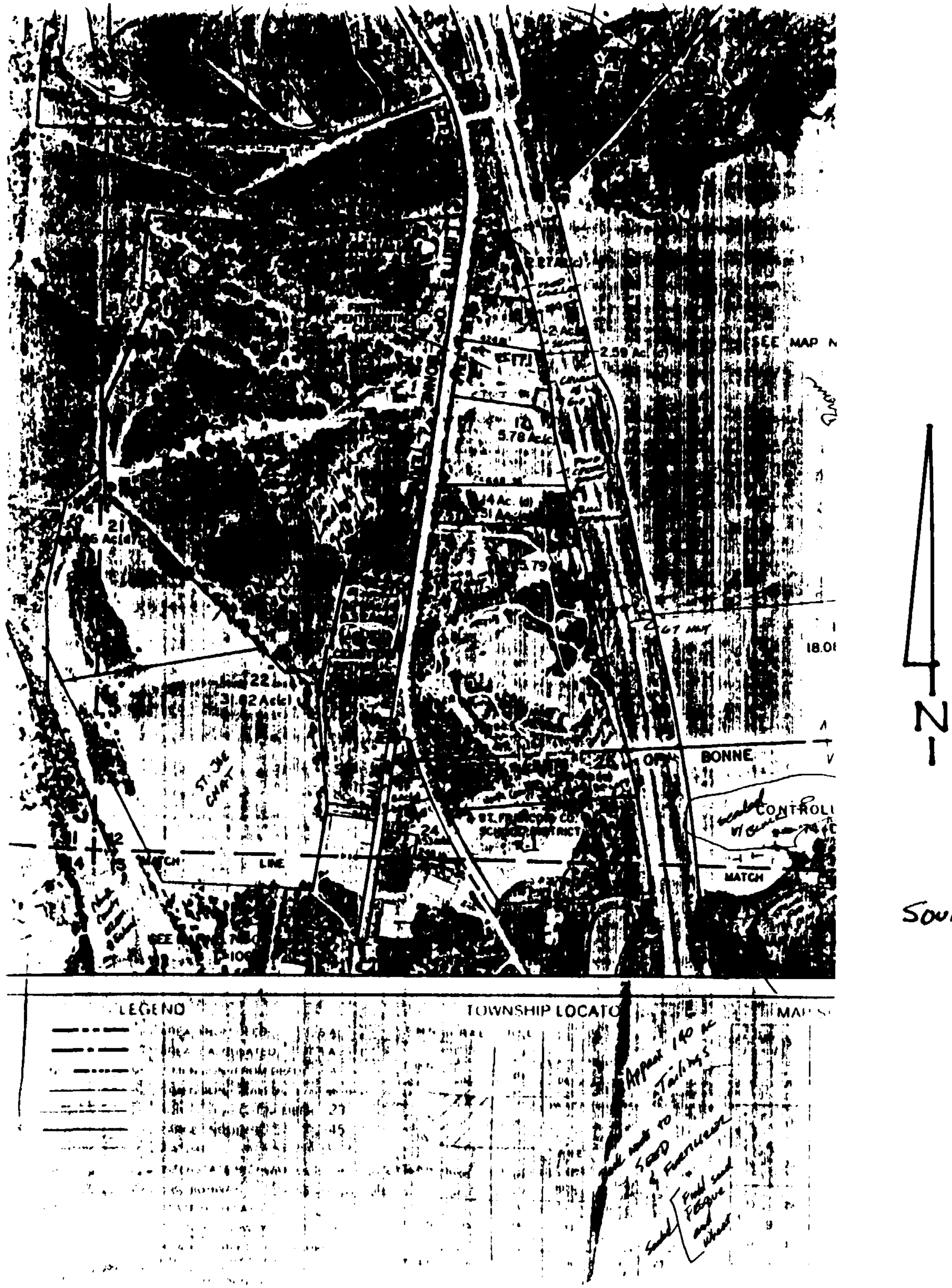
EFFECTIVE DATE.

AUGUST 19, 1985


RIVER
R4E
R5E
2
47
1
6
COUNTY
67
HIGHWAY
E
ZONE A
10
11
ZONE A
12
ZONE A
7
TAILINGS
CHAT
Seven
Creek
14
City of Bonne Terre
AREA NOT INCLUDED
ZONE A = 100 YR-FLOOD
ZONE
A
A
24
ZONE A
ZONE A
23
MISSOURI
PACIFIC



SOURCE: St. FRANCOIS, MO
OWNERSHIP MAP
1" = 400' (ORIGINAL)
AERIAL PHOTO.
AUG 1982



SOURCE: ST. FRANCOIS, M
OWNERSHIP MAP
1" = 400' (ORIGINAL)
AREIAL PHOTO.
AUG 1982

90TH CONGRESS 1st Session | SENATE | DOCUMENT No. 19

MINERAL AND WATER RESOURCES OF MISSOURI

REPORT

OF THE

UNITED STATES GEOLOGICAL SURVEY

AND THE

MISSOURI DIVISION OF GEOLOGICAL SURVEY AND WATER RESOURCES

WITH THE COLLABORATION OF THE

UNITED STATES BUREAU OF MINES
UNITED STATES SOIL CONSERVATION SERVICE
MISSOURI STATE PARK BOARD
MISSOURI WATER RESOURCES BOARD
MISSOURI WATER POLLUTION BOARD

AND THE

UNIVERSITY OF MISSOURI

AND WITH A SUPPLEMENT ON

WATER RESOURCE DEVELOPMENT PROJECTS IN MISSOURI

BY THE

DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS

PREPARED AT THE REQUEST OF

Senator STUART SYMINGTON and Senator EDWARD V. LONG of Missouri

APRIL 6, 1967.—Ordered to be printed with illustrations

U.S. GOVERNMENT PRINTING OFFICE
77-278 O WASHINGTON : 1967

concentration of calcium, magnesium, and bicarbonate. In general, water in the Gasconade River Basin is of good quality and is suitable for most uses. Because of the high hardness of the water, softening is desirable for some uses.

Other Missouri River tributaries

Information about other streams draining into the Missouri River in the State is given in the following table:

Station	Drainage area (square miles)	Years of record	Average discharge (cubic feet per second)	Extremes of discharge	
				Maximum (cubic feet per second)	Minimum (cubic feet per second)
Mill Creek at Oregon	4.90	9	1.71	2,640	0
East Fork Fishing River at Excelsior Springs	20.0	14	11.0	23,100	0
Crooked River near Richmond	159	16	88.2	27,000	0
Wakenda Creek at Carrollton	248	16	126	7,000	.2
Burge Branch near Arrow Rock	0.33	5	0.11	134	0
Shiloh Branch near Marshall	2.87	12	1.34	934	0
Moniteau Creek near Fayette	81	15	32.1	4,330	0
Petite Saline Creek near Boonville	182	16	103	6,120	0
Moreau River near Jefferson City	531	15	319	23,000	.1
Big Hollow near Fulton	4.05	2	....	936	0
Rumbo Branch at Danville	1.40	5	.61	434	0
Loutre River at Mineola	202	16	102	12,900	0
Coldwater Creek near St. Louis	43.6	4	....	6,170	4.2

LOWER MISSISSIPPI RIVER BASIN

Meramec River Basin

The Meramec River and its two principal tributaries, the Bourbeuse and Big Rivers, lie wholly within the State and drain 3,980 square miles of east-central Missouri. The river rises in the Ozark Plateau and flows in a general northeasterly direction, entering the Mississippi River about 12 miles south of St. Louis. The basin is 110 miles long. Its greatest width, near the center of the basin, is 60 miles, gradually decreasing to about 10 miles near its mouth.

The basin is a highly dissected plateau with land surface sloping gently to the north and becoming increasingly more rugged to the south. The elevation ranges from 1,500 feet above mean sea level at its headwaters to about 450 feet at its mouth. There are many sinkholes in the basin. Many large springs cause the high sustained base flow of the Meramec and its tributaries.

The Meramec and its tributaries are used for municipal supply, recreation, fish propagation, and for the dilution and carrying away of municipal and industrial wastes.

The water resources of the Meramec Basin at present are relatively undeveloped. Because of its proximity to large centers of population and its recreation potential, the basin has been studied intensively to insure future orderly development.

7-2-64

MISSOURI GEOLOGICAL SURVEY AND WATER RESOURCES, ROLLA, MISSOURI

MGS LOG NO. 22002

COUNTY St. Francois - City of Bonneterre [redacted]

COMPANY OR OWNER Lead Belt Water Co.

FARM WELL NO.

LOCATION SEC 13 T 37N R 4E

CONTRACTOR Ben Emily

DRILLER

COMMENCED COMPLETED 7-24-64

PRODUCTION 375 G.P.M.

CASING RECORD 535 of 10" csg.

WATER RECORD 525

SOURCE OF LOG

REMARKS 530' of 14" & 190' of 10" hole

ELEV. 926 Keeve, 5-31-73

TOTAL DEPTH 720

SWL 350'

NO. SAMPLES 142 Act. 51 Feat. on

FORMATION	FROM (FT)	TO (FT)	FORMATION	FROM (FT)	TO (FT)
Derby	0	45			
Davis	45	165			
Bonneterre	165	540			
Lamotte	540	720			

U.S. Department of Commerce
Economics and Statistics Administration
BUREAU OF THE CENSUS

CENSUS '90

1990 CPH-1-27

1990 Census of Population and Housing

Summary Population and Housing Characteristics

Missouri

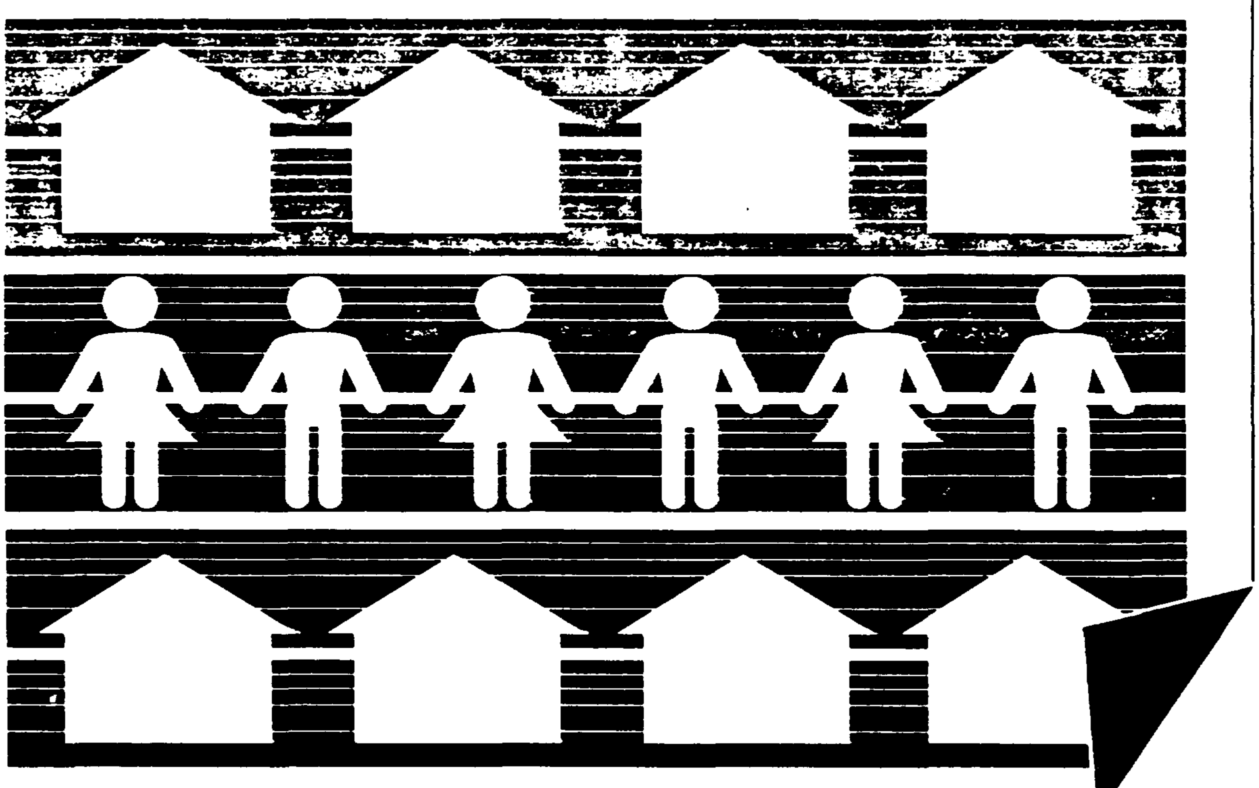


Table 6. **Household, Family, and Group Quarters Characteristics: 1990**—Con.

[For definitions of terms and meanings of symbols, see text]

State County Place and [In Selected States] County Subdivision	Persons in households	All households	Family households: Total	Family households: Married-couple family	Family households: Female householder, no husband present	Nonfamily households: Total	Nonfamily households: Householder living alone: Total	Householder living alone: 65 years and over: Total	Householder living alone: 65 years and over: Female	Persons per—: Household	Persons per—: Family	Persons in group quarters: Total	Persons in group quarters: Institutionalized persons	Persons in group quarters: Other persons in group quarters
COUNTY—Con.														
Ripley County	12 171	4 788	3 522	2 908	460	1 266	1 184	705	556	2.54	3.02	132	132	-
St. Charles County	210 682	74 331	57 815	49 956	5 910	16 516	13 357	3 603	2 877	2.83	3.25	2 225	1 537	688
St. Clair County	8 267	3 499	2 441	2 148	222	1 058	986	608	478	2.36	2.88	190	190	-
Ste. Genevieve County	15 792	5 707	4 416	3 878	374	1 291	1 153	625	476	2.77	3.21	245	181	64
St. Francois County	45 725	17 670	13 101	10 871	1 788	4 569	4 084	2 225	1 809	2.59	3.04	3 179	2 832	347
~~St. Louis County~~	~~975 815~~	~~380 110~~	~~270 421~~	~~219 468~~	~~40 657~~	~~109 689~~	~~93 532~~	~~35 078~~	~~28 674~~	~~2.57~~	~~3.10~~	~~17 714~~	~~12 586~~	~~5 128~~
Saline County	21 872	8 903	6 121	5 020	846	2 782	2 499	1 412	1 148	2.46	3.00	1 651	882	769
Schuyler County	4 176	1 729	1 234	1 085	117	495	467	324	260	2.42	2.93	60	60	-
Scotland County	4 696	1 956	1 325	1 165	123	631	586	375	311	2.40	3.01	126	126	-
Scott County	38 895	14 761	10 950	8 767	1 810	3 811	3 490	1 921	1 597	2.63	3.12	481	481	-
Shannon County	7 515	2 917	2 199	1 931	204	718	665	374	296	2.58	3.03	98	83	15
Shelby County	6 725	2 809	1 919	1 685	185	890	838	536	438	2.39	2.98	217	217	-
Stoddard County	28 214	11 383	8 366	7 024	1 052	3 017	2 801	1 606	1 323	2.48	2.94	681	439	242
Stone County	18 889	7 885	5 975	5 367	460	1 910	1 696	947	696	2.40	2.77	189	184	5
Sullivan County	6 103	2 615	1 809	1 588	161	806	754	519	415	2.33	2.87	223	185	38
Taney County	24 386	10 321	7 497	6 578	699	2 824	2 495	1 324	1 024	2.36	2.79	1 175	272	903
Texas County	21 255	8 441	6 195	5 314	663	2 246	2 088	1 177	931	2.52	3.00	221	199	22
Vernon County	17 979	7 301	5 085	4 262	659	2 216	2 043	1 127	908	2.46	3.02	1 062	692	370
Warren County	19 302	7 070	5 423	4 745	470	1 647	1 423	684	503	2.73	3.15	232	208	24
Washington County	19 755	6 982	5 420	4 437	725	1 562	1 374	710	527	2.83	3.25	625	615	10
Wayne County	11 366	4 607	3 417	2 849	410	1 190	1 067	640	478	2.47	2.88	177	146	31
Webster County	22 977	8 391	6 569	5 715	627	1 822	1 666	926	723	2.74	3.16	776	759	17
Worth County	2 369	1 037	679	601	54	358	336	230	181	2.28	2.90	71	71	-
Wright County	16 558	6 510	4 725	4 059	518	1 785	1 679	998	780	2.54	3.06	200	199	1
St. Louis city	385 916	164 931	90 945	50 557	33 864	73 986	64 677	26 519	20 788	2.34	3.21	10 769	5 900	4 869
PLACE AND COUNTY SUBDIVISION														
Adrian city, Bates County	1 519	628	428	365	55	200	190	118	101	2.42	3.02	63	57	6
Advance city, Stoddard County	1 071	488	321	259	49	167	162	108	92	2.19	2.78	68	68	-
Affton CDP, St. Louis County	21 075	8 919	6 263	5 230	815	2 656	2 369	1 209	1 003	2.36	2.87	31	17	14
Agency town, Buchanan County	642	201	176	157	14	25	17	8	6	3.19	3.40	-	-	-
Airport Drive village, Jasper County	818	309	250	224	19	59	52	22	15	2.65	2.98	-	-	-
Alba city, Jasper County	465	190	129	109	18	61	59	36	32	2.45	3.05	-	-	-
Albany city, Gentry County	1 891	837	530	441	75	307	292	206	180	2.26	2.87	67	67	-
Aldrich village, Polk County	76	28	21	19	2	7	6	6	5	2.71	3.19	-	-	-
Alexandria city, Clark County	341	138	93	77	8	45	38	13	9	2.47	3.00	-	-	-
Allendale town, Worth County	58	32	16	14	2	16	15	11	5	1.81	2.44	-	-	-
Allenville village, Cape Girardeau County	69	27	19	17	2	8	6	3	3	2.56	3.05	-	-	-
Alma city, Lafayette County	446	178	124	107	13	54	47	36	32	2.51	3.08	-	-	-
Altamont town, Daviess County	188	74	50	45	3	24	24	14	11	2.54	3.22	-	-	-
Altenburg city, Perry County	307	129	87	80	3	42	41	25	21	2.38	3.01	-	-	-
Alton city, Oregon County	689	320	194	145	33	126	124	91	76	2.15	2.85	3	3	-
Amazonia town, Andrew County	257	99	74	59	11	25	21	14	9	2.60	3.03	-	-	-
Amity town, De Kalb County	99	39	25	24	-	14	12	7	4	2.54	3.24	-	-	-
Amoret city, Bates County	212	84	64	50	10	20	19	12	9	2.52	2.94	-	-	-
Amsterdam city, Bates County	237	84	67	57	8	17	15	6	4	2.82	3.24	-	-	-
Anderson city, McDonald County	1 278	570	360	273	61	210	195	116	99	2.24	2.87	154	98	56
Annada town, Pike County	70	25	16	15	-	9	9	5	4	2.80	3.81	-	-	-
Annapolis city, Iron County	363	155	99	75	21	56	53	33	26	2.34	3.06	-	-	-
Anniston town, Mississippi County	288	115	85	70	5	30	25	12	7	2.50	2.86	-	-	-
Appleton City city, St. Clair County	1 212	562	331	281	44	231	218	147	124	2.16	2.89	68	68	-
Arbela town, Scotland County	40	18	13	11	1	5	5	3	3	2.22	2.69	-	-	-
Arbyrd city, Dunklin County	597	252	163	127	28	89	87	57	48	2.37	2.97	-	-	-
Arcadia city, Iron County	609	280	176	150	21	104	95	68	61	2.18	2.75	-	-	-
Archie city, Cass County	799	332	235	204	26	97	95	63	53	2.41	2.95	-	-	-
Arcola village, Dade County	72	39	23	20	2	16	16	11	7	1.85	2.43	-	-	-
Argyle town	178	66	46	42	3	20	19	17	14	2.70	3.39	-	-	-
Maries County	7	2	2	1	1	-	-	-	-	3.50	3.00	-	-	-
Osage County	171	64	44	41	2	20	19	17	14	2.67	3.41	-	-	-
Arkoe town, Nodaway County	64	24	17	17	-	7	6	3	1	2.67	3.29	-	-	-
Armstrong city, Howard County	310	130	91	67	20	39	36	29	21	2.38	2.88	-	-	-
Arnold city, Jefferson County	18 717	6 664	5 281	4 328	713	1 383	1 140	365	317	2.81	3.17	111	111	-
Arrow Rock town, Saline County	70	33	24	20	3	9	8	4	3	2.12	2.50	-	-	-
Asbury city, Jasper County	220	75	63	53	5	12	10	5	3	2.93	3.21	-	-	-
Ashburn town, Pike County	51	21	14	9	3	7	7	5	5	2.43	3.00	-	-	-
Ash Grove city, Greene County	1 128	479	332	280	37	147	143	109	87	2.35	2.86	-	-	-
Ashland city, Boone County	1 252	540	342	270	62	198	178	97	87	2.32	2.92	-	-	-
Atlanta city, Macon County	411	163	119	99	16	44	42	33	28	2.52	3.03	-	-	-
Augusta city, St. Charles County	263	109	73	70	1	36	33	25	15	2.41	3.05	-	-	-
Aullville village, Lafayette County	72	29	20	15	4	9	9	2	2	2.48	2.90	-	-	-
Aurora city, Lawrence County	6 459	2 728	1 798	1 470	258	930	856	541	462	2.37	2.98	-	-	-
Auxvasse city, Callaway County	821	345	228	189	32	117	113	86	72	2.38	3.04	-	-	-
Ava city, Douglas County	2 836	1 285	776	607	139	509	481	319	270	2.21	2.91	102	102	-
Avilla town, Jasper County	99	37	27	24	2	10	6	3	-	2.68	3.04	-	-	-
Avondale city, Clay County	550	219	157	118	29	62	50	15	12	2.51	2.96	-	-	-
Bagnell town, Miller County	89	36	25	21	3	11	10	4	4	2.47	2.96	-	-	-
Baker village, Stoddard County	8	3	2	2	-	1	1	-	-	2.67	3.50	-	-	-
Bakersfield village, Ozark County	292	106	81	64	13	25	24	16	14	2.75	3.27	-	-	-
Baldwin Park village, Cass County	85	35	22	19	2	13	11	5	4	2.43	3.18	-	-	-
Ballwin city, St. Louis County	21 700	7 849	6 191	5 392	618	1 658	1 378	360	298	2.76	3.16	116	116	-
Baring city, Knox County	182	77	46	40	4	31	27	17	13	2.36	3.09	-	-	-
Barnard city, Nodaway County	234	104	64	49	10	40	39	28	18	2.25	2.98	-	-	-
Barnett city, Morgan County	215	80	56	50	3	24	24	11	11	2.69	3.36	-	-	-
Barnhart CDP, Jefferson County	4 848	1 481	1 307	1 156	119	174	134	41	30	3.27	3.49	63	31	32
Bates City village, Lafayette County	197	72	56	44	9	16	15	9	5	2.74	3.14	-	-	-
Battlefield town, Greene County	1 526	535	468	415	42	67	47	9	9	2.85	3.06	-	-	-
Bella Villa city, St. Louis County	708	303	206	171	28	97	92	55	45	2.34	2.91	-	-	-
Bell City city, Stoddard County	469	194	131	100	30	63	62	29	23	2.42	3.05	-	-	-
Belle city	1 218	536	331	269	53	205	198	131	114	2.27	3.02	-	-	-
Maries County	1 069	475	291	235	49	184	178	119	106	2.25	3.00	-	-	-
Osage County	149	61	40	34	4	21	20	12	8	2.44	3.15	-	-	-
Bellefontaine Neighbors city, St. Louis County	10 468	4 454	3 152	2 622	424	1 302	1 206	739	610	2.35	2.85	454	454	-
Bellerive village, St. Louis County	238	86	75	62	8	11	10	2	2	2.77	2.97	-	-	-
Bellflower city, Montgomery County	413	142	108	87	17	34	30	19	13	2.91	3.40	-	-	-

Table 6. Household, Family, and Group Quarters Characteristics: 1990—Con.

[For definitions of terms and meanings of symbols, see text]

State County Place and [In Selected States] County Subdivision	Persons in households	All households	Family households: Total	Family households: Married-couple family	Family households: Female householder, no husband present	Nonfamily households: Total	Nonfamily households: Householder living alone: Total	Householder living alone: 65 years and over: Total	Householder living alone: 65 years and over: Female	Persons per—: Household	Persons per—: Family	Persons in group quarters: Total	Persons in group quarters: Institutionalized persons	Persons in group quarters: Other persons in group quarters
PLACE AND COUNTY SUBDIVISION—Con.														
Bel-Nor village, St. Louis County	2 644	1 092	735	526	178	357	328	129	112	2.42	3.04	291	112	179
Bel-Ridge village, St. Louis County	3 185	1 176	807	444	299	369	313	81	58	2.71	3.28	14	14	-
Belton city, Cass County	17 881	6 393	4 873	4 003	697	1 520	1 280	400	338	2.80	3.23	269	109	160
Benton city, Scott County	575	239	169	151	13	70	67	44	38	2.41	2.95	-	-	-
Benton City town, Audrain County	139	49	42	39	1	7	6	4	3	2.84	3.10	-	-	-
Berger city, Franklin County	247	94	71	58	12	23	22	9	7	2.63	3.11	-	-	-
Berkeley city, St. Louis County	12 423	4 280	3 279	1 946	1 120	1 001	853	262	200	2.90	3.34	27	16	11
Bernie city, Stoddard County	1 847	783	546	427	98	237	224	139	114	2.36	2.88	-	-	-
Bertrand city, Mississippi County	655	266	202	156	40	64	62	35	29	2.46	2.83	37	37	-
Bethany city, Harrison County	2 817	1 307	815	696	96	492	474	302	250	2.16	2.79	188	188	-
Bethel town, Shelby County	117	61	31	24	7	30	29	20	13	1.92	2.74	-	-	-
Beverly Hills city, St. Louis County	660	275	173	97	64	102	97	39	24	2.40	3.08	-	-	-
Bevier city, Macon County	643	271	179	150	26	92	81	51	41	2.37	2.97	-	-	-
Bigelow village, Holt County	32	13	9	6	3	4	2	1	-	2.46	2.89	-	-	-
Big Lake village, Holt County	170	87	59	54	5	28	27	11	6	1.95	2.37	-	-	-
Billings city, Christian County	989	403	285	229	42	118	110	64	50	2.45	2.99	-	-	-
Birch Tree city, Shannon County	599	255	166	147	16	89	84	51	43	2.35	3.00	-	-	-
Birmingham village, Clay County	222	78	59	51	7	19	18	12	11	2.85	3.37	-	-	-
Bismarck city, St. Francois County	1 557	604	441	355	69	163	152	104	83	2.58	3.06	22	11	11
Blackburn city	308	110	83	76	3	27	26	19	14	2.80	3.29	-	-	-
Lafayette County	22	7	6	6	-	1	1	1	1	3.14	3.50	-	-	-
Saline County	286	103	77	70	3	26	25	18	13	2.78	3.27	-	-	-
Black Jack city, St. Louis County	5 857	2 000	1 596	1 295	234	404	339	121	106	2.93	3.33	271	271	-
Blackwater city, Cooper County	221	92	64	54	5	28	24	15	11	2.40	2.86	-	-	-
Blairstown city, Henry County	185	75	50	43	3	25	23	12	9	2.47	3.10	-	-	-
Bland city	640	257	176	141	20	81	69	39	33	2.49	3.05	11	3	8
Gasconade County	640	257	176	141	20	81	69	39	33	2.49	3.05	11	3	8
Osage County	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Blodgett town, Scott County	202	81	58	43	12	23	21	9	8	2.49	3.00	-	-	-
Bloomfield city, Stoddard County	1 709	744	494	391	86	250	236	157	139	2.30	2.88	91	91	-
Bloomsdale city, Ste. Genevieve County	353	142	102	92	5	40	39	28	23	2.49	3.04	-	-	-
Blue Eye town, Stone County	112	45	29	26	2	16	16	9	6	2.49	3.31	-	-	-
Blue Springs city, Jackson County	39 896	13 529	11 055	9 426	1 285	2 474	2 012	616	520	2.95	3.29	257	240	17
Blythedale village, Harrison County	130	58	33	28	4	25	24	17	14	2.24	3.12	-	-	-
Bogard city, Carroll County	228	93	69	57	7	24	23	15	12	2.45	2.87	-	-	-
Bolckow city, Andrew County	253	93	65	58	7	28	28	11	6	2.72	3.46	-	-	-
Bolivar city, Polk County	~~5 866~~	~~2 407~~	1 620	1 372	205	987	816	492	423	~~2.36~~	2.82	979	237	742
Bonne Terre city, St. Francois County	3 819	1 474	1 037	819	180	437	405	264	228	2.59	3.17	52	41	11
Boonville city, Cooper County	5 870	2 303	1 660	1 338	263	843	782	454	384	2.55	2.92	1 225	1 031	194
Bosworth city, Carroll County	334	149	103	95	6	46	43	30	25	2.24	2.71	-	-	-
Bourbon city, Crawford County	1 188	479	311	263	38	168	157	98	83	2.48	3.16	-	-	-
Bowling Green city, Pike County	2 822	1 191	762	581	142	429	405	231	195	2.37	3.04	154	119	35
Bragg City town, Pemiscot County	117	44	35	33	2	9	9	7	3	2.66	3.06	-	-	-
Brandsville city, Howell County	167	56	44	33	8	12	11	6	6	2.98	3.39	-	-	-
Branson city, Taney County	3 603	1 678	1 070	914	127	608	556	342	294	2.15	2.70	103	70	33
Brashear city, Adair County	318	123	93	81	10	30	30	25	22	2.59	3.10	-	-	-
Braymer city, Caldwell County	886	388	257	199	50	131	122	84	71	2.28	2.65	-	-	-
Breckenridge city, Caldwell County	418	188	117	94	14	71	64	43	37	2.22	2.83	-	-	-
Breckenridge Hills village, St. Louis County	5 404	2 091	1 449	950	396	642	523	202	151	2.58	3.08	-	-	-
Brentwood city, St. Louis County	8 149	4 025	2 130	1 725	333	1 895	1 657	484	395	2.02	2.78	1	1	-
Bridgeton city, St. Louis County	17 238	6 793	4 933	4 075	646	1 860	1 534	555	463	2.54	3.00	541	541	-
Brimson village, Grundy County	72	27	21	21	-	6	6	3	3	2.67	3.14	-	-	-
Bronaugh city, Vernon County	211	88	61	48	9	27	27	13	10	2.40	2.95	-	-	-
Brookfield city, Linn County	4 711	2 133	1 301	1 093	168	832	771	483	395	2.21	2.88	177	176	1
Brookline village, Greene County	283	111	93	84	3	18	17	6	5	2.55	2.82	-	-	-
Brooklyn Heights village, Jasper County	116	46	35	31	3	11	7	1	-	2.52	2.77	-	-	-
Browning city	331	146	94	75	14	52	50	28	24	2.27	2.86	-	-	-
Linn County	255	109	75	63	9	34	32	15	13	2.34	2.84	-	-	-
Sullivan County	76	37	19	12	5	18	18	13	11	2.05	2.95	-	-	-
Brownington town, Henry County	84	38	26	22	-	12	12	6	3	2.21	2.77	-	-	-
Brumley town, Miller County	81	32	25	16	8	7	5	2	2	2.53	2.72	-	-	-
Brunswick city, Chariton County	1 023	480	283	219	49	197	186	121	97	2.13	2.82	51	50	1
Bucklin city, Linn County	616	277	168	142	22	109	105	75	56	2.22	2.95	-	-	-
Buckner city, Jackson County	2 873	1 007	782	617	129	225	208	107	93	2.85	3.28	-	-	-
Buffalo city, Dallas County	2 312	1 039	644	479	137	395	377	264	220	2.23	2.88	102	102	-
Bunceton city, Cooper County	341	144	95	78	12	49	44	27	24	2.37	2.94	-	-	-
Bunker city	390	152	104	83	15	48	45	30	22	2.57	3.22	-	-	-
Dent County	159	59	39	34	4	20	17	13	9	2.69	3.46	-	-	-
Reynolds County	231	93	65	49	11	28	28	17	13	2.48	3.08	-	-	-
Burgess town, Barton County	97	31	22	20	2	9	7	5	3	3.13	3.91	-	-	-
Burlington Junction city, Nodaway County	624	267	169	147	18	98	97	63	56	2.34	3.06	10	-	10
Butler city, Bates County	3 913	1 717	1 133	903	180	584	545	360	309	2.28	2.84	186	186	-
Butterfield village, Barry County	248	98	73	65	3	25	21	11	10	2.53	2.96	-	-	-
Byrnes Mill city, Jefferson County	1 578	559	438	374	44	121	87	28	23	2.82	3.20	-	-	-
Cabool city, Texas County	1 931	871	546	429	105	325	315	211	177	2.22	2.88	75	75	-
Cainsville city, Harrison County	387	189	116	99	9	73	71	48	37	2.05	2.68	-	-	-
Cairo village, Randolph County	282	110	74	64	9	36	36	26	19	2.56	3.30	-	-	-
Caledonia village, Washington County	142	65	38	30	4	27	27	25	21	2.18	3.00	-	-	-
Calhoun city, Henry County	450	187	126	103	20	61	58	39	27	2.41	3.03	-	-	-
California city, Moniteau County	3 333	1 471	927	751	146	544	516	323	283	2.27	2.93	132	132	-
Callao city, Macon County	332	137	93	82	10	44	36	20	13	2.42	3.00	-	-	-
Calverton Park village, St. Louis County	1 404	523	408	343	56	115	101	43	30	2.68	3.10	-	-	-
Camden city, Ray County	238	92	66	55	6	26	22	11	9	2.59	3.03	-	-	-
Camden Point city, Platte County	373	125	106	96	7	19	16	10	9	2.98	3.28	-	-	-
Camdenton city, Camden County	2 544	1 105	717	540	148	388	352	201	178	2.30	2.90	17	17	-
Cameron city	4 632	1 989	1 293	1 054	198	696	647	375	337	2.33	2.96	199	199	-
Clinton County	3 737	1 544	1 053	853	164	491	446	237	208	2.42	2.99	54	54	-
De Kalb County	895	445	240	201	34	205	201	138	129	2.01	2.83	145	145	-
Campbell city, Dunklin County	2 075	904	576	441	114	328	305	206	159	2.30	2.94	90	90	-
Canalou city, New Madrid County	319	128	97	86	9	31	30	18	14	2.49	2.95	-	-	-
Canton city, Lewis County	1 969	870	533	444	63	337	304	178	154	2.26	2.91	654	-	654

[For definitions of terms and meanings of symbols, see text]

State / County / Place and [In Selected States] County Subdivision	Persons in households	All households	Family households: Total	Family households: Married-couple family	Family households: Female householder, no husband present	Nonfamily households: Total	Householder living alone: Total	Householder living alone, 65 years and over: Total	Householder living alone, 65 years and over: Female	Persons per—: Household	Persons per—: Family	Persons in group quarters: Total	Persons in group quarters: Institutionalized persons
PLACE AND COUNTY SUBDIVISION— Con.													
Delta city, Cape Girardeau County	450	168	126	109	14	42	38	28	22	2.68	3.11	-	-
Dennis Acres village, Newton County	157	61	42	30	11	19	14	3	3	2.57	3.12	-	-
Denver village, Worth County	53	23	16	15	1	7	6	2	-	2.30	2.81	-	-
Des Arc village, Iron County	173	75	49	43	5	26	24	16	12	2.31	2.94	-	-
Desloge city, St. Francois County	4 045	1 591	1 175	966	168	416	367	193	160	2.54	3.00	105	105
De Soto city, Jefferson County	5 [illegible]	2 410	1 661	1 292	286	749	691	405	350	2.48	3.03	26	18
Des Peres city, St. Louis County	8 [illegible]	2 763	2 430	2 229	157	333	294	144	105	3.00	3.24	102	102
De Witt city, Carroll County	[illegible]	51	35	29	3	16	15	10	8	2.45	3.09	-	-
Dexter city, Stoddard County	7 437	3 246	2 144	1 641	423	1 102	1 012	603	514	2.29	2.86	122	122
Diamond town, Newton County	775	293	223	185	32	70	64	38	30	2.65	3.07	-	-
Diehlstadt town, Scott County	145	57	40	35	5	17	15	12	10	2.54	3.13	-	-
Diggins village, Webster County	258	94	76	63	11	18	16	13	8	2.74	3.12	-	-
Dixon city, Pulaski County	1 558	684	428	320	80	256	245	144	124	2.28	2.97	27	27
Doniphan city, Ripley County	1 674	805	453	332	104	352	337	237	207	2.08	2.83	39	39
Doolittle city, Phelps County	599	234	182	157	21	52	43	20	15	2.56	2.91	-	-
Dover town, Lafayette County	115	54	35	30	3	19	18	10	7	2.13	2.57	-	-
Downing city, Schuyler County	359	171	108	94	11	63	59	50	44	2.10	2.65	-	-
Drexel city	936	373	256	218	31	117	111	73	60	2.51	3.15	-	-
Bates County	101	35	29	25	3	6	6	1	1	2.89	3.24	-	-
Cass County	835	338	227	193	28	111	105	72	59	2.47	3.14	-	-
Dudley city, Stoddard County	271	116	79	64	12	37	34	23	18	2.34	2.73	-	-
Duenweg city, Jasper County	940	370	269	203	59	101	88	37	33	2.54	3.03	-	-
Duquesne village, Jasper County	1 191	468	371	322	40	97	74	31	23	2.54	2.85	38	20
Eagleville town, Harrison County	275	122	83	70	9	39	36	24	16	2.25	2.77	-	-
East Lynne town, Cass County	289	93	77	68	8	16	13	6	6	3.11	3.44	-	-
Easton city, Buchanan County	232	86	63	57	2	23	21	12	7	2.70	3.24	-	-
East Prairie city, Mississippi County	3 347	1 326	945	693	210	381	351	218	181	2.52	3.07	69	69
Edgar Springs city, Phelps County	215	85	61	54	7	24	24	15	14	2.53	3.11	-	-
Edgerton city, Platte County	565	195	156	142	6	39	36	23	17	2.90	3.32	-	-
Edina city, Knox County	1 244	576	361	294	55	215	209	145	128	2.16	2.81	39	-
Edmundson village, St. Louis County	1 111	429	288	205	65	141	112	43	33	2.59	3.18	-	-
Eldon city, Miller County	4 341	1 948	1 177	893	229	771	711	429	359	2.23	2.91	78	78
El Dorado Springs city, Cedar County	3 672	1 661	1 014	811	169	647	609	412	331	2.21	2.88	158	158
Ellington city, Reynolds County	994	435	278	209	53	157	149	96	84	2.29	2.90	-	-
Ellisville city, St. Louis County	7 176	2 607	2 021	1 767	198	586	514	309	269	2.75	3.18	369	354
Ellsinore town, Carter County	405	179	112	100	12	67	67	50	39	2.26	3.02	-	-
Elmer city, Macon County	91	40	25	19	3	15	14	10	9	2.28	3.00	-	-
Elmira village, Ray County	70	21	20	17	2	1	1	1	-	3.33	3.40	-	-
Elmo city, Nodaway County	179	83	53	49	2	30	29	21	19	2.16	2.77	-	-
Elsberry city, Lincoln County	1 898	780	509	416	77	271	246	156	136	2.43	3.08	-	-
Elvins city, St. Francois County	1 391	511	392	314	68	119	103	59	47	2.72	3.15	-	-
Emerald Beach village, Barry County	172	86	71	67	4	15	14	7	5	2.00	2.18	-	-
Eminence city, Shannon County	576	263	158	124	29	105	98	65	57	2.19	2.87	6	4
Emma city	194	82	57	48	5	25	25	18	16	2.37	2.95	-	-
Lafayette County	86	35	25	25	-	10	10	6	4	2.46	3.04	-	-
Saline County	108	47	32	23	5	15	15	12	12	2.30	2.88	-	-
Eolia village, Pike County	389	161	116	97	16	45	43	32	27	2.42	2.92	-	-
Essex city, Stoddard County	531	213	160	130	19	53	51	33	25	2.49	2.94	-	-
Esther city, St. Francois County	1 071	422	294	210	69	128	116	63	58	2.54	3.07	-	-
Ethel town, Macon County	71	31	21	18	3	10	10	8	5	2.29	2.90	-	-
Eugene town, Cole County	141	59	36	27	9	23	23	14	9	2.39	3.22	-	-
Eureka city, St. Louis County	4 358	1 465	1 183	987	159	282	232	93	77	2.97	3.34	325	325
Everton city, Dade County	325	132	85	74	9	47	41	30	28	2.46	3.06	-	-
Ewing city, Lewis County	463	188	137	118	16	51	50	36	27	2.46	2.96	-	-
Excelsior Estates village	274	88	72	56	10	16	12	-	-	3.11	3.40	-	-
Clay County	3	1	1	1	-	-	-	-	-	3.00	3.00	-	-
Ray County	271	87	71	55	10	16	12	-	-	3.11	3.41	-	-
Excelsior Springs city	9 788	3 854	2 684	2 139	440	1 170	1 052	541	438	2.54	3.10	566	298
Clay County	9 612	3 782	2 627	2 090	435	1 155	1 042	532	430	2.54	3.11	566	298
Ray County	176	72	57	49	5	15	10	9	8	2.44	2.70	-	-
Exeter city, Barry County	597	259	175	141	27	84	82	46	36	2.31	2.90	-	-
Fairfax city, Atchison County	699	320	197	170	21	123	116	85	77	2.18	2.84	-	-
Fair Grove city, Greene County	919	344	273	224	44	71	65	37	30	2.67	3.03	-	-
Fair Play city, Polk County	442	172	112	90	17	60	57	36	30	2.57	3.33	-	-
Fairview town, Newton County	298	118	81	66	11	37	33	22	21	2.53	3.10	-	-
Farber city, Audrain County	418	162	119	105	12	43	37	29	24	2.58	3.04	-	-
Farley village, Platte County	217	75	62	57	1	13	11	6	5	2.89	3.23	-	-
Farmington city, St. Francois County	8 927	3 749	2 522	2 079	378	1 227	1 136	610	522	2.38	2.98	2 671	2 557
Fayette city, Howard County	2 272	1 015	641	481	132	374	344	219	186	2.24	2.85	616	114
Fenton city, St. Louis County	3 290	1 103	955	849	74	148	128	47	32	2.98	3.23	56	56
Ferguson city, St. Louis County	22 009	8 750	6 089	4 505	1 273	2 661	2 293	920	736	2.52	3.06	277	205
Ferrelview village, Platte County	338	180	72	55	14	108	102	12	10	1.88	3.10	-	-
Festus city, Jefferson County	7 794	3 120	2 228	1 717	429	892	811	409	349	2.50	3.01	311	295
Fidelity town, Jasper County	233	89	68	51	14	21	18	5	1	2.62	2.99	2	-
Fillmore city, Andrew County	256	109	78	60	11	31	30	17	7	2.35	2.77	-	-
Fisk city, Butler County	422	184	115	90	16	69	67	41	29	2.29	2.96	-	-
Flat River city, St. Francois County	4 749	1 884	1 298	972	279	586	531	298	259	2.52	3.07	74	59
Fleming city, Ray County	130	53	31	25	2	22	22	10	6	2.45	3.13	-	-
Flemington village, Polk County	141	62	45	36	7	17	15	11	5	2.27	2.67	-	-
Flint Hill village, St. Charles County	229	80	63	53	6	17	17	12	12	2.86	3.30	-	-
Flordell Hills city, St. Louis County	950	371	254	154	87	117	101	53	45	2.56	3.15	-	-
Florida village, Monroe County	2	1	1	1	-	-	-	-	-	2.00	2.00	-	-
Florissant city, St. Louis County	50 144	19 177	14 438	12 014	1 872	4 739	4 137	1 604	1 338	2.61	3.06	1 062	928
Foley city, Lincoln County	209	89	57	49	6	32	31	15	13	2.35	3.05	-	-
Ford City town, Gentry County	29	10	9	9	-	1	1	1	1	2.90	3.11	-	-
Fordland city, Webster County	523	229	146	108	31	83	77	58	44	2.28	2.93	-	-
Forest City city, Holt County	380	157	106	85	12	51	46	30	24	2.42	3.01	-	-
Foristell city	144	54	39	28	8	15	14	2	1	2.67	3.23	-	-
St. Charles County	130	47	34	23	8	13	12	2	1	2.77	3.35	-	-
Warren County	14	7	5	5	-	2	2	-	-	2.00	2.40	-	-
Forsyth city, Taney County	1 153	574	350	302	40	224	213	139	118	2.01	2.60	22	22

Modern Physical Geography

Third Edition

Arthur N. Strahler
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Cover photo Landsat image of a portion of the East African Rift Valley System. Shown here is Gregory's Rift in southern Kenya. In the floor of the rift valley lie Lake Naivasha (top of frame) and a volcanic crater, Longonot. Refer to legend of Plate E.2 for further details. (NASA ERTS 2188-07055, 29 July 1975. Reproduced by permission of EOSTAT.)

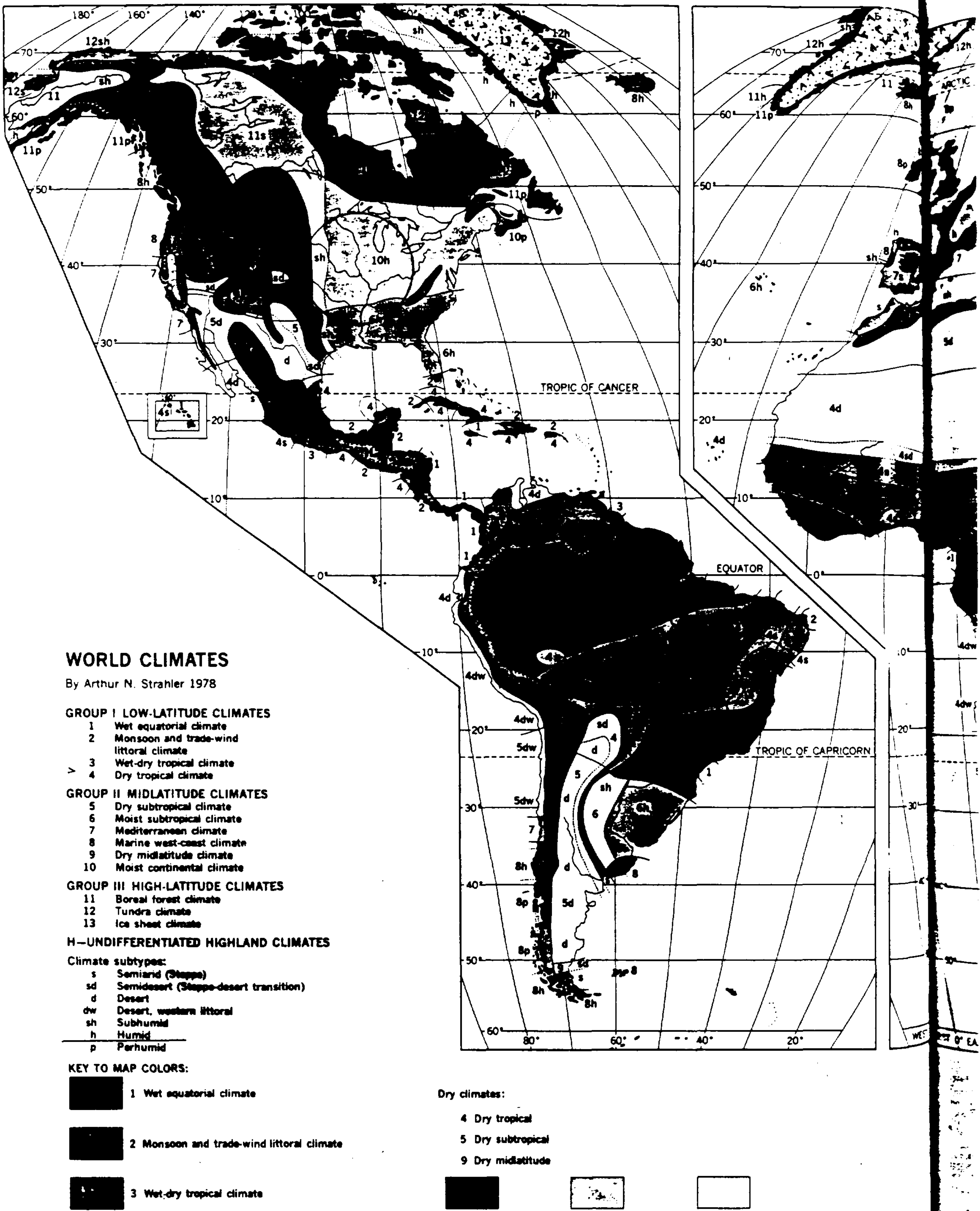
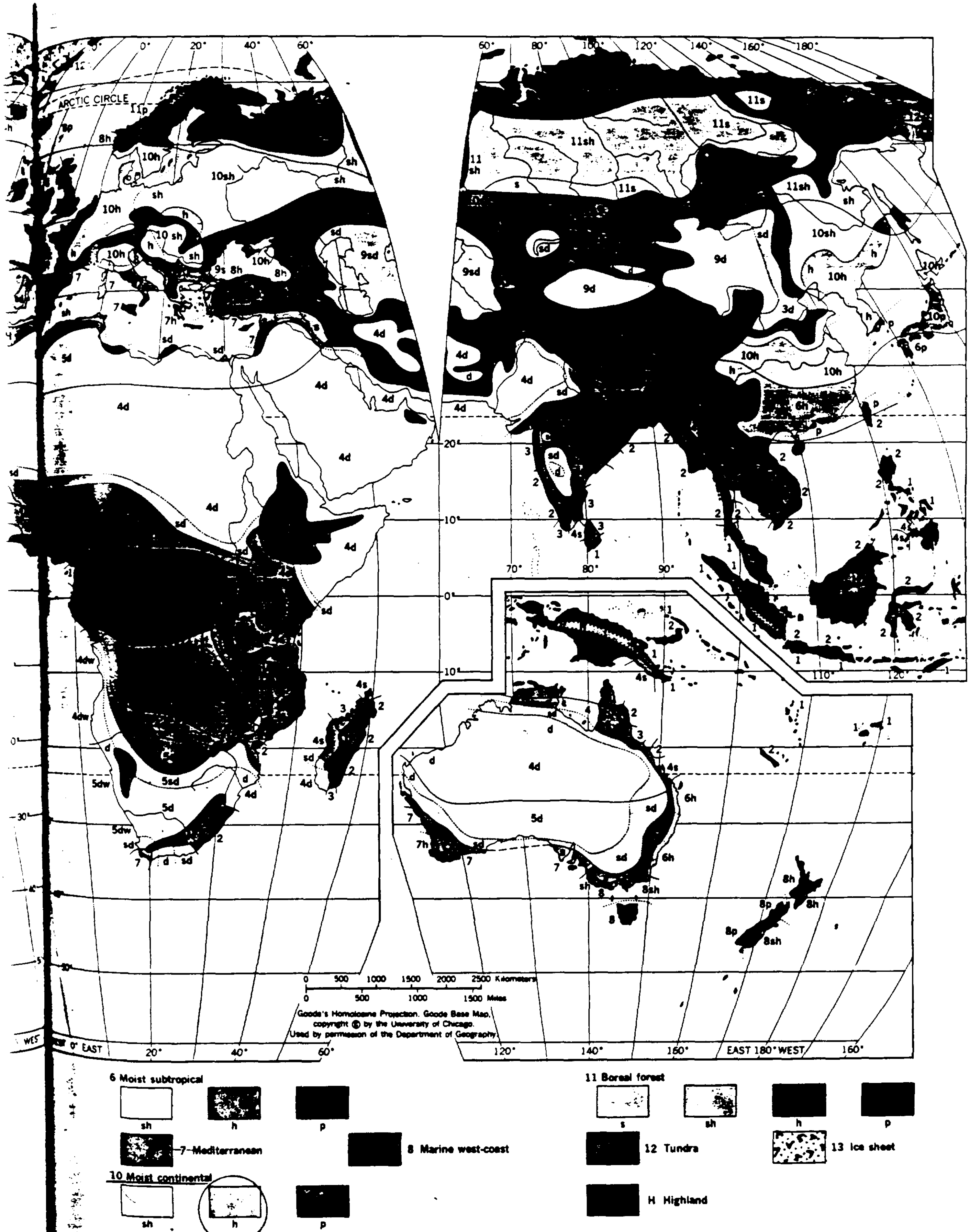


Plate C.2

World Climates



HUMID

World Climates

Plate C.2

in Kazakhstan. The climate is semidesert (9sd), with an annual precipitation total of only 13 cm (5 in.), or less than half that of Pueblo. The annual temperature range is extremely great—37C° (67F°)—and winters are bitterly cold. Winter-month temperatures average below freezing (0°C, 32°F) for five consecutive months.

10. *Moist continental climate*

Latitude range: 30° to 55°N (Europe: 45° to 60°)

Located in central and eastern parts of North America and Eurasia in the midlatitude zone, this climate is in the polar-front zone—the battleground of polar and tropical air masses. Seasonal temperature contrasts are strong, while day-to-day weather is highly variable. Ample precipitation throughout the year is increased in summer by the invading mT air mass. Eastern maritime locations are perhumid. Cold winters are dominated by cP and continental arctic (cA) air masses from subarctic source regions. In eastern Asia (China, Korea, Japan), the monsoon effect is strongly evident in a summer rainfall maximum and a relatively dry winter. In Europe, the moist continental climate lies in a higher latitude belt (45° to 60°N) and receives precipitation from the mP air mass coming from the North Atlantic.

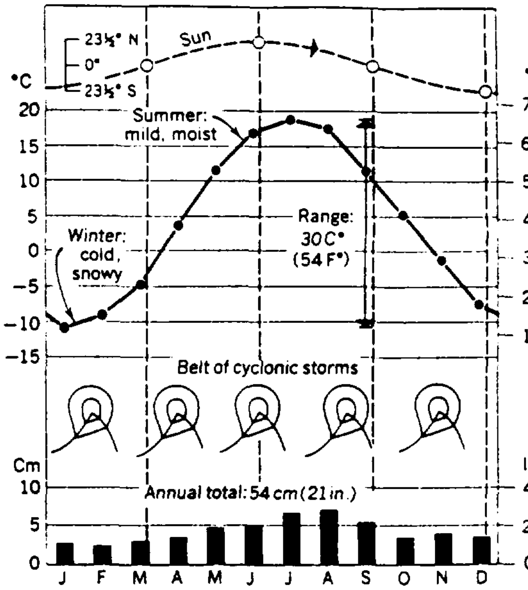


FIGURE 9.26 Moscow, Russia, lat. 56°N, has an annual range about the same as Madison; but summers in Moscow are not as warm.

Major regions of occurrence: Eastern parts of the United States and southern Canada, northern China, Korea, Japan, and central and eastern Europe.

Example. Figure 9.25 is a climograph for Madison, Wisconsin, lat. 43°N, in the American Midwest. The annual temperature range is very large (31C°, 56F°). Summers are warm but winters are cold, with three consecutive monthly means well below freezing (0°C, 32°F). Precipitation is ample in all months and totals 81 cm (32 in.), giving a humid climate. There is a well-developed summer maximum of precipitation when the mT air mass invades and thunderstorms are formed along moving cold fronts and squall lines. Much of the winter precipitation is in the form of snow, which remains on the ground for long periods.

Example. Figure 9.26 is a climograph for Moscow, Russia, at lat. 56°N. This location is over 600 km (1000 mi) farther north than Madison, so Moscow summers are not as warm and winters are colder. Annual total precipitation at Moscow is less (54 cm, 21 in.) than at Madison, with smaller monthly amounts throughout the year. Winter precipitation, largely snow, remains on the ground for many months.

Example. Figure 9.27 is a climograph for Inchon, Korea, at lat. 37½°N. Compared with Madison, Inchon has

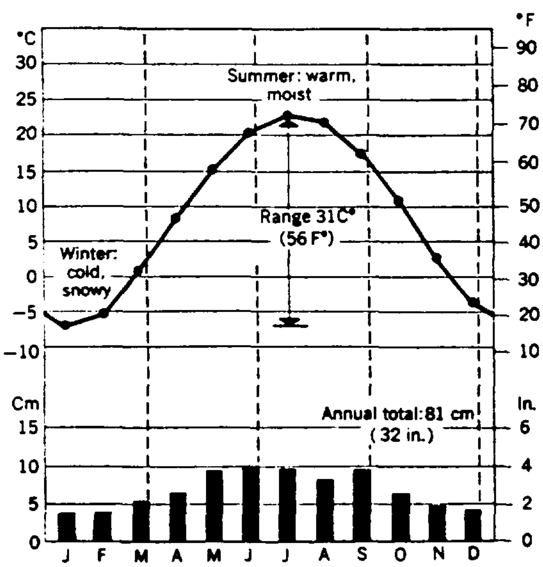


FIGURE 9.25 Madison Wisconsin, lat. 43°N, has cold winters and warm summers, making the annual temperature range very large.

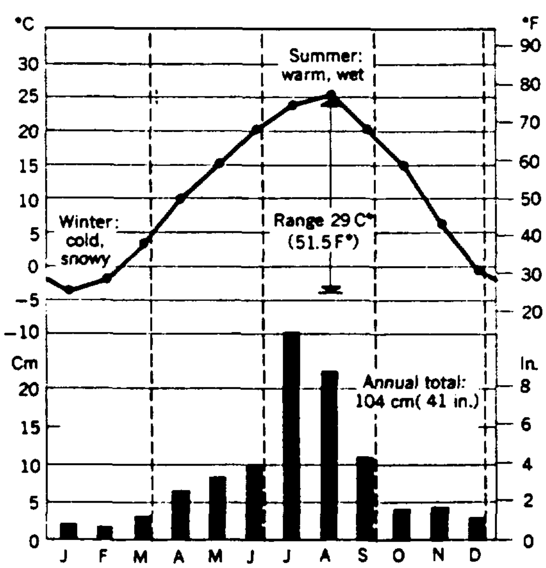


FIGURE 9.27 Inchon, Korea, lat. 37½°N, has two very rainy months during the summer monsoon, but very little precipitation in winter.

somewhat warmer summers; but winters are not as cold. The major difference in the two stations is in the precipitation cycle. Inchon shows the Asiatic monsoon effect with two very rainy summer months and greatly diminished precipitation in winter. Because of the summer monsoon, with influx of a maritime air mass from the western Pacific Ocean, Inchon has a larger total annual precipitation (104 cm, 41 in.) than either Madison or Moscow.

GROUP III: HIGH-LATITUDE CLIMATES

11. Boreal forest climate

Latitude range: 50° to 70°N

This is a continental climate with long, bitterly cold winters and short, cool summers. This climate occupies the source region of the cP air mass, which is cold, dry, and stable in the winter. Invasions of the very cold cA air mass are common. The annual range of temperature is greater than that for any other climate, attaining a value of 60C° (110F°) in Siberia. Precipitation is substantially increased in summer, when maritime air masses penetrate the continent with traveling cyclones; but the total annual precipitation is small. Although much of the boreal forest climate is classed as humid, with precipitation of 50 to 100 cm (20 to 40 in.), large areas in western Canada and Siberia have annual precipitation totals of less than 40 cm (16 in.) and are classed as subhumid (11sh) or semiarid (11s) subtypes.

Major regions of occurrence: Central and western Alaska; Canada, from Yukon Territory to Labrador; southernmost Greenland; Iceland; and Eurasia, from northern Europe across all of Siberia to the Pacific Coast.

Example. Figure 9.28 is a climograph for Fort Vermilion in Alberta, Canada, at lat. 58°N. The very great annual temperature range (41C°, 74F°) is typical for North America. Monthly mean air temperatures are below freezing (0°C, 32°F) for seven consecutive months. The summers are short and cool. Precipitation shows a marked annual cycle with a strong summer maximum; but the total annual precipitation is only 31 cm (12 in.), and the climate can be characterized as subhumid (11sh). Although precipitation in winter is small, a snow cover remains over solidly frozen ground throughout the entire winter. On the same climograph, temperature data are shown for Yakutsk, U.S.S.R., a Siberian city at lat. 62°N. The enormous annual range is evident, also the extremely low winter-month means. January reaches a mean of about −45°C (−50°F), making this region the coldest on earth except for the ice-sheet interiors of Antarctica and Greenland. Precipitation is not shown for Yakutsk, but the annual total is only about 18 cm (7 in.)—much less than for Fort Vermilion—and indicates a semiarid climate subtype (11s).

12. Tundra climate

Latitude range: 60° to 75°N and S

The tundra climate occupies the arctic coastal fringes, dominated by cP, mP, and cA air masses, and with frequent cyclonic storms. Winters are long and severe. There is a very short mild season, which many climatologists do not recognize as a true summer. A moderating influence of the nearby ocean water prevents winter temperatures from falling to the extreme lows found in the continental interior. The tundra climate ranges from a humid subtype (12h) bordering the Atlantic Ocean to subhumid (12sh) and semiarid (12s) subtypes bordering the Arctic Ocean.

Major regions of occurrence: Arctic slope of North America, Hudson Bay region and Baffin Island, Greenland coast, northern Siberia bordering the Arctic Ocean, and Antarctic Peninsula.

Example. Figure 9.29 is a climograph for Upernivik, located on the west coast of Greenland at lat. 73°N. A

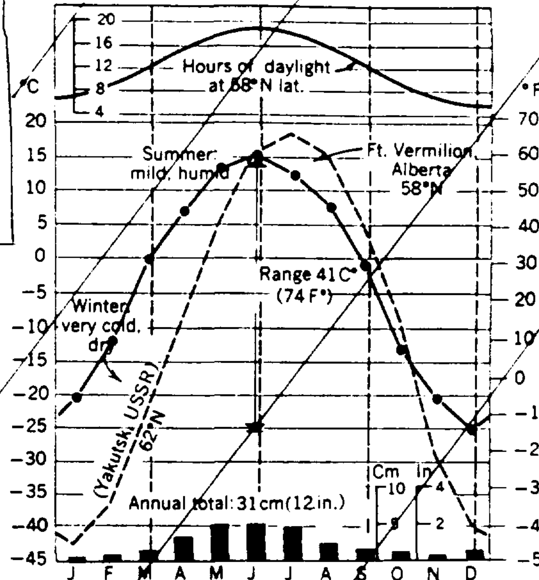


FIGURE 9.28 Extreme winter cold and a very great annual range in temperature characterize the boreal forest climate, illustrated by these climographs for Fort Vermilion in Alberta, Canada, and Yakutsk, Russia.

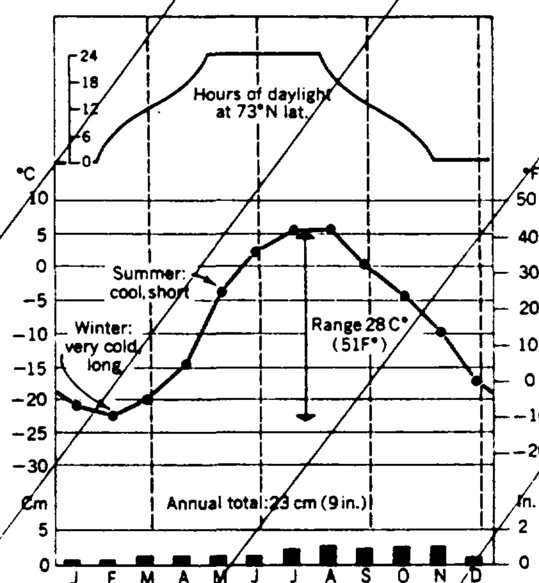


FIGURE 9.29 Upernivik, Greenland, lat. 73°N, is a typical arctic tundra station.

BONNE TERRE

THE FIRST HUNDRED YEARS AND MORE

(314) 358-2260

By ROBERT M. BLACKWELL

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Anthony LaGrave

THE BEGINNING

In March, 1864, the St. Joseph Lead Company was incorporated in New York for one million dollars and the stock turned over to Lyman W. Gilbert, who disposed of most of it at half its face value. In April 1864, 946 acres of land were purchased from Anthony LaGrave and his wife Mary (Valle) LaGrave for $25,000.00 cash and three notes of $25,000.00 each. Though LaGrave and many others had done quite a bit of primitive surface mining in this area for many years, this incorporation of the St. Joseph Lead Company was the beginning of the "St. Joe Lead Mines" and the town of Bonne Terre.

It is believed the name, St. Joseph, was taken from one of the old mines of the district, Mine a' Joe; though this mine at that time was located near the present town of Desloge. And it is generally agreed that the name, Bonne Terre, was given the area by the French because of the richness of the earth in mineral wealth, but it has been suggested that the scenic beauty of the forests, streams, and rolling hills could have been the reason for the appellation.

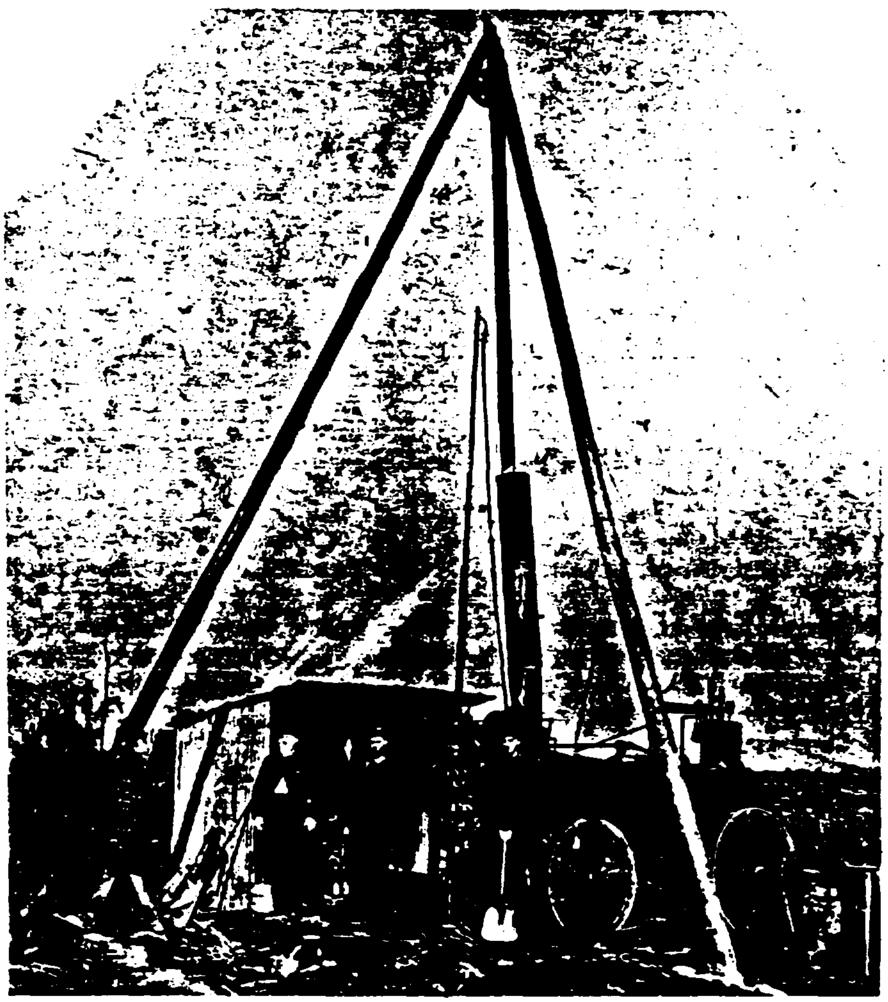
THE FOUNDERS

The names of several men stand out in the early history of St. Joe and the town of Bonne Terre: J. Wyman Jones, Charles Bunyan Parsons, Hugh N. Camp, and Albert Shepard. J. Wyman Jones was President of the company from 1865 to 1904, C. B. Parsons was Superintendent from 1867 to 1910, Hugh N. Camp was appointed Treasurer in 1868, and Albert Shepard brought the first diamond drill to Bonne Terre in 1869. They have been followed by many men who, no doubt, were just as efficient and capable, but it appears much credit must be given these men for their skill and determination during the early years of the struggling lead company.

J. Wyman Jones received some stock in the fledgling company as payment on a debt and attended a stockholders' meeting out of curiosity. Though he knew nothing about mining, the result of his questions at the meeting was that he and members of the board journeyed to the "diggings" to see just what they had. Despite the fact that it was necessary to ride horseback 13 miles through mud and wilderness from the nearest railroad to reach the site and that the mining was being conducted in a haphazard and simple fashion, they were impressed with the possibilities.

Horizontal sheets of lead, four to eight feet below the surface of the ground lined the banks of

Turkey Run (Slime Creek). When they returned to New York, J. Wyman Jones was elected to the presidency and immediately began plans for a systematic development of the mines. In 1886 he met Mr. C. B. Parsons and persuaded him to come to the mines as Superintendent. When Mr. Parsons assumed his duties in June 1867 there was one frame house, near the present site of the Congregational Church, and about two dozen log cabins. The mining methods of that day were of the crudest. The lead sheets were uncovered, blasted into blocks that could be handled, broken again with hammers, then passed through a Blake's Crusher and a pair of Cornish Rolls to be pulverized. After the rocks had been "jigged" up and down in water to separate the lead from the stone, the lead was thrown into old-fashioned stone ovens, called "reverberatory furnaces", to melt, then ladled into iron moulds. A single furnace manned by six men would turn out thirty-two pigs of seventy-two pounds each in twenty-four hours if carefully attended. Much difficulty was caused by water, either too much or too little. During heavy rains the holes would fill up and during a drought there was no water to wash the mineral.



An Early Steam-Powered Diamond Drill

THE DIAMOND DRILL

Mr. Parsons attacked all these problems energetically and soon the company was producing more lead than ever before. He started mining deeper, so the men could work during the sleet, snow and ice of winter, and found quite a large body of ore. J. Wyman Jones had heard of a new invention called the diamond drill and felt it could prove useful in discovering new bodies of mineral, but the stockholders would not approve the expenditure of money for the "experiment". Mr. Jones and Mr. Camp decided to finance the project themselves and in 1869 Mr. Albert Shepard brought the first diamond drill to Bonne Terre, or "The St. Joe Lead Mines". Both names were used then and for several years afterward. Mr. Shepard stayed with the company and his wife opened a hotel called the Shepard House, which was located at 203 E. School Street where the residence of W. O. Rasch now stands. The old Shepard House was moved in sections to its present location, next to the library, and is reputed to be the oldest frame building in Bonne Terre.

The advent of the diamond drill marked the beginning of mining as we know it today. Shafts were sunk and drifts and headings blasted; however, since this was before electricity and the compressed air drill, progress was necessarily very slow.

During these early years the young company was continuously hampered by lack of working capital. In 1868 $30,000.00 was borrowed from the stockholders and it was not until 1881 that the debt was finally paid–the principal and interest amounting to $175,000.00.

THE TOWN

During this period a village was slowly growing up near the mines and mill, but it was not until much later that the town as we know it accelerated its growth. Big River Mills had been a thriving community long before and many miners lived in East Bonne Terre (Elvinstown), because of the vile-smelling sulphur fumes emanating from the furnaces near the mines. In 1868 the first post office, called "Bonteer", was established about a mile west of the mines in the Bonne Terre Heights area.

Here a quote from a column, written in a cynical and humorous vein by L. L. Richardson of St. Louis, might be appropriate:

"In the early days of St. Francois County a post office was established at Big River Mills for the north section of the territory up until 1868. When the St. Joseph Lead Company came in that section was known as just plain 'The Mines'.

"When a community began to form at the St. Joe Mines, and they were hauling lead ore to

"I would be glad if you would stop in to see me on one of your many trips to St. Louis. I live just east of St. Mary's Hospital in Richmond Heights.

"Sincerely,

"Emily de Pyster Conover"

Writer's Note: This letter was taken in its entirety from the 1950 files of the Bonne Terre Bulletin. Though there may be some discrepancies between it and other statements herein it is felt that the letter is a significantly important contribution to this booklet.

1900

The period from 1900 into the 20's was the era of growth, consolidation, and stabilization for the Town of Bonne Terre and its principal industry, the St. Joseph Lead Company. In 1901 the railroad to Leadwood was completed and more men were employed, swelling the population of Bonne Terre. About 1904 or 1905 the Bonne Terre Foundry was started, an industry that is still operating.

It is said there were 7000 people living here in 1907 and it is generally agreed that those years were the high point as far as population is concerned. The present population is just a little over 3000.

A few automobiles made their appearance (Roscoe Parsons is reputed to have had the first), and some livery stables started renting cars as well as horses.

Harold House with 1919 Model T

America entered the first World War and Bonne Terre boys were sent to the fields of Flanders. Everybody remembers the wild celebration the night Armistice was declared. Bonfires and firearms made it seem for awhile as if Bonne Terre was starting a war of its own.

All of this time the City of Bonne Terre was unincorporated, with no city government. Law enforcement was handled by the sheriff's office and constables and the St. Joe Lead Company took care of almost everything. Apparently there had been quite a bit of agitation over the years to incorporate the town and this was finally done in 1917 under the commission form of government with a mayor and two councilmen. It has been stated that Dr. Hicks Matkin was our first mayor, but

In the early 1920's there was a strong movement among some of the townspeople to try to pass a city stock law. Horses, cows, mules, and hogs roamed the streets at will. The hogs were especially aggravating since they seemed to take perverse pleasure in establishing a wallow in the middle of muddy streets. Practically every householder had a fence, its primary purpose being to keep the animals out rather than in. On the first round the proponents of the stock law were soundly beaten and the smoke from this battle had hardly cleared away when the City Council provoked another storm by voting to remove the watering trough which was located at School and Division Streets. This watering trough had been erected by T. E. Phillips, as a service to his rural customers, and the merchants descended on the Council in a body demanding to know why they were driving away business, if they wanted to force all the farmers to go to Farmington, and if they didn't want anybody to come into their town, why didn't they build a fence around it? They also threatened to institute proceedings to disincorporate the town. This battle and the bigger one which followed in 1924, when the stock law was finally passed, remind all of us of the fights over garbage collection and parking meters in the 1950's.

The 1920's were interesting and prosperous years for the Town of Bonne Terre and the St. Joseph Lead Company. With the introduction of modern methods and machinery the Company's production was at an all time high. In 1916, the Company had erected the chat conveyor forming the "mountainous pile of gray chat," which, together with the other local chat piles, are distinguishing landmarks for all the towns of the Lead Belt. Prior to that, the chat had been hauled away in railway cars to be dumped wherever feasible and the rest was flushed down Slime Creek. Innumerable lawsuits were filed by farmers on Big River protesting that the slime had ruined their land, but so far as is known none were ever successful.

Since 1922, when the first Chamber of Commerce was organized, the business and professional men of the town have been organizing for the purpose of promoting business, industry, and the general welfare. After a few years most of these organizations have folded, but they have always come back. At the present time we have a very active Chamber of Commerce and Community Services Corporation. In 1923 the Chamber of Commerce raised $16,000.00 and succeeded in getting the Rice-Stix Shirt Factory to come to town. This factory provided employment for quite a number of people until it closed in 1963.

NOTE: Since the above was written the local Community Service Corporation has succeeded in getting the factory reopened by another concern March 18, 1964, with approximately the same number of employees—75.

In 1923 the Ford Motor Co. optioned quite a bit of land around Bonne Terre and did extensive drilling for lead for about two years. Several local men were employed in this project while it lasted.

In 1925 the die-hards, who were still opposed to the stock law, petitioned to change the form of city government, succeeded in getting an election held, and were defeated 4 to 1.

In 1927 the new concrete highway was opened to St. Louis, passenger trains were cut to two a day, and the local papers were complaining about the HUGE trucks hogging the highway. Also, there was some agitation to persuade the merchants to continue receiving their freight by rail since the railroaders lived here and were dependent to some extent on local business to keep their jobs.

In 1928 a new Chamber of Commerce was organized with the avowed purpose of completing two projects—a tourist camp ground at the lake and buying a fire truck. Bonne Terre had never had a fire truck. Fire houses had been built at strategic locations in various parts of the city and equipped with carts, hoses, etc., but this was a makeshift remedy at best and the people of the town felt they needed better fire protection. Old timers still tell of the many disastrous fires Bonne Terre suffered in those days. The fire truck was purchased in 1929 with the St. Joe Lead Company paying a large portion of the bill.

The other project, a tourist camp ground at the lake, had been talked of before, but was never started, though the idea was revived some years later during W. P. A. days. For years various organizations used the grounds around the lake for affairs. Many will remember the 4th of July American Legion picnics which were held there.

In 1929 the St. Joe Lead Company bought out the Desloge Lead Company and sold its interest in the Mississippi River & Bonne Terre Railroad and the Rivermines Power Plant.

All during the 1920's, until the highway to St. Louis was opened, baseball was a big thing in Bonne Terre. The ball park was located in the Huff Court area and crowds of six or seven hundred were not at all uncommon. One Sunday 1400 fans crowded the park to watch a particularly interesting team play. The team always ran a full-page ad in the local paper and the results of the game were published on the front page. By 1928, however, local interest had dwindled so that the team was disbanded and the ball park torn down.

THE 1930's

The 1930's were a bad time for Bonne Terre and the St. Joseph Lead Company. St. Joe borrowed ten million dollars to carry it through and stockpiled the lead. At various times the men worked one week a month, two weeks a month, or three weeks a month. Practically no other jobs at all could be found, the banks closed, and the merchants did their best to extend credit to their customers.

However, there were quite a number of accomplishments and events which benefited the community during this ten years.

In the early 1930's a company came in and started mining dolomite about two miles south of town. This company, Valley Dolomite, is still operating, has always had about a hundred employees, and, since the beginning, has been a strong economic factor in the life of Bonne Terre.

The road to the highway was paved, the business section paved, and, after the W. P. A. projects were started, many sidewalks built, and other streets paved.

In 1936 the Post Office Department instituted city delivery in Bonne Terre. During this period gas mains were laid in Bonne Terre and the method of cooking and heating underwent a drastic change. By the time the 1940's rolled around prosperity had returned, war clouds were on the horizon, and the people of Bonne Terre could look back and feel that, comparatively speaking, they had survived the depression very well.

THE 1940's

The war years in Bonne Terre were the same as everywhere else, everybody working and many young men called to the defense of their country.

After the war another Chamber of Commerce was organized, this time called the Business & Professional Men's Association, and it succeeded in getting the city government changed to an aldermanic form of government, with Dr. Hicks Matkin still the mayor. The St. Joseph Lead Company had always been singularly free of labor troubles with small disturbances in 1913, 1917, and 1924, but in 1948 the miners were out on strike for three and one-half months. This disagreement was settled and the men went back to work in September of 1948.

From then until now the Company has embarked on a program of development and expansion, opening up new mines in other areas, with the result that it decided its first mine, the Bonne Terre mine, was no longer a paying proposition. The mine was closed in 1961 and the people of the town were gloomy for awhile, though the main offices are still located here. Then in 1962 the men were out on an eight months strike, but since this has been settled amicably everyone has bright hopes for the future of the Company and the town.

Since 1948, when the city government was changed, the town has battled and fought its way to many progressive improvements. The streets are better, the city has acquired a new fire truck with an efficient fire-fighting crew, there is a modern police force, adequate garbage collection, and the sewer system is nearing completion. A heel factory, a chemical plant and several other small industries are in operation, and a group of active, civic-minded men are continuously working to persuade new industry to locate in Bonne Terre. The people are learning to stand on their two feet and work together, and with this attitude the future of the town is assured.

THE HOSPITAL

Mining has always been a hazardous occupation. The St. Joseph Lead Company had concentrated on energetically promoting safety in its mines and has succeeded in cutting accidents to a minimum. In the early days, however, there were many men injured, some killed, and the people of the area who had never been in the mines considered mining a very dangerous calling. The writer concealed the fact from his parents that he was going underground when he first worked for the Company. However, a fall on the steps at old No. 1 and the resultant sojourn in the hospital let the cat out of the bag.

Original Bonne Terre Hospital, Founded in 1911

In the early years the St. Joe Lead Company established a hospital for its employees on the western edge of East Bonne Terre where the St. Francois Mill & Farm Supply building is now located. Later a building was erected on a lot on Allen St., between School and Elm, and the hospital moved into this building. In 1911 the Bonne Terre Hospital Association was incorporated, the hospital moved to its present location, and people other than employees of St. Joe admitted. The old hospital building was moved from its location on Allen Street, remodeled, and became a home for the nurses. In 1927 an addition was made to the hospital building and in 1949 a very extensive and modern addition was completed. At the present time the Bonne Terre Hospital ranks with some of the finest in the country.

BONNE TERRE'S GREAT COMEBACK

ST. LOUIS GLOBE-DEMOCRAT

June 17/18, 1967

Bonne Terre's Great Comeback

Lead Belt Town, In Deep Economic Trouble Six Years Ago, Is Again Thriving Community

by Ted Schafers, Globe-Democrat Public Affairs Editor

No one really knows how Bonne Terre, Mo. got its name. Some historians of the Lead Belt say that early residents found the name painted on a postal station and adopted it when the town was founded in 1825.

A French-born settler who came into the area to do a little open-pit mining and found a payload is believed responsible.

Translated from the French, Bonne Terre, which is 60 miles southwest of St. Louis, means "Good Earth". The land around this Lead Belt area certainly has poured forth its bounty.

It was at Bonne Terre that St. Joseph Lead began its first major lead mining and milling operations and, from there plotted its widespread lead belt operations. The Bonne Terre mines total output has accounted for over 30,000,000 tons of lead ore worth in excess of $125,000,000.

St. Joseph Lead Company has been a dominant influence in Bonne Terre for 102 years. It still maintains its southeastern headquarters in the city (administrative, engineering and some shop work) although its mining and smelting operations have moved elsewhere in the Lead Belt.

Therefore, in 1961, when the company announced it was closing its big Bonne Terre mine, the economic life of this Missouri community was shaken to the core. A devasting, 247-day strike against the firm in 1963 added to the city's woes.

However, Bonne Terre leaders didn't lay back and moan about the good old days. The underground mine shafts were silent but there was plenty of "Good Earth" above to lure new people, new industry and other important economic developments.

New Subdivisions

New highways began attracting land and lake developers, who foresaw thousands flocking to this area for recreational and permanent homesites. Interstate Highway 55 and improved U.S. 67 has made Bonne Terre only an hour's easy drive from St. Louis. This same network of improved highways also has opened up new jobs in St. Louis and St. Louis County for Bonne Terre residents.

Eleven industries have established new plants or expanded facilities in Bonne Terre. While total new employment is counted at only 200 jobs, business leaders are quick to cite U. S. Chamber of Commerce figures which estimate that 200 new breadwinners stimulate more non-manufacturing jobs, sell 100 homes; create $710,000 in new personal income and $331,000 in retail sales annually.

Economic growth as measured by savings is impressive.

The First State Bank of Bonne Terre has seen its assets increase $2,000,000 since 1961. The Bonne Terre Savings & Loan Association in the same period has doubled its assets from $3,010,000 to $6,122,000. For a town of about 4000 residents, that's an impressive record, although these financial institutions serve an area far greater than just Bonne Terre.

The topography of the land lends itself easily to lake development, and a number of new subdivisions designed for both recreational and permanent homesites are under construction.

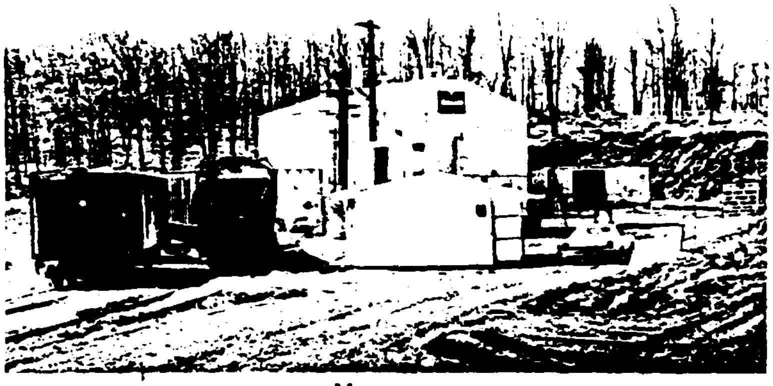
One of the largest is Terre du Lac (Land of Lakes) sponsored by Big River Lakes Development Company which is opening 7500 homesites around nine lakes and two and a half miles of riverfront, embracing 5000 acres.

Arterial roads being laid into this project are wider than Lindbergh Boulevard. Although there are a number of other lakeside real estate developments around Bonne Terre, Terre du Lac has caused the most excitement because Fred Weber, a highly successful St. Louis highway contractor, is behind the project.

Bonne Terre boosters say that as soon as Interstate 55 is completed to Festus, state highway officials plan to make the present two-lane U. S. 67 a four-lane divided road as far as Farmington.

"When that happens watch this area take off," said Wallace A. Gieringer, director of industrial development for Missouri Natural Gas Company.

New industries locating in Bonne Terre in the last few years include: Unidynamics Corp., subsidiary of Universal Match; Monsanto Chemical Co.; C & R Products Co. (manufacturers of pole line hardware for utilities); Service Heel Corp.; Purity Products Corp. and Barad Mfg. Co.



Monsanto

One economic note was an observation by a businessman that "not a single piece of rental property is currently available in Bonne Terre."

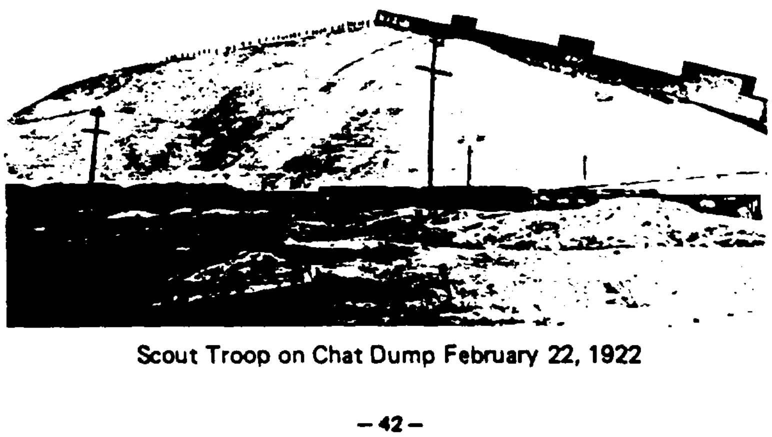
Some of the land with river frontage in this area has jumped 1000 per cent in the last five years.

One businessman moaned as he recalled how he was offered 1000 acres in what is now the Terre du Lac development for $15 an acre in 1961. Now half-acre lots are selling for as much as $3000 as roads and utilities are added.

Promising Future

Two strange landmarks from Bonne Terre's past never fail to intrigue visitors.

One is a huge mound of chat piled 160 feet high near the old lead mine. Some of the home-builders are using this fine rock residue as a base before laying concrete. St. Joseph Lead Co. permits local builders to haul it away free, but anyone selling it must pay a fee.



Scout Troop on Chat Dump February 22, 1922

The other oddity is a stretch of ground south of U. S. 67 which resembles a slice out of the Sahara Desert. This is known as a "slime pond", where chat in slurry form was dumped by St. Joseph Lead Company after deciding to stop building up pyramids in the town.

"Now we grind the chat much finer and it is being sold for agricultural limestone" said Elmer S. Jones, manager of the Southeast Division of St. Joseph Lead Company.

This company has spent over $100 million in opening new Missouri lead and iron mines in the past 10 years. Although most of its mines and mills are some distances from Bonne Terre, the company demonstrates its fondness for the city by retaining its headquarters here. Mr. Jones has lived in Bonne Terre for over 40 years.

At the time the Bonne Terre lead ore mine was closed in 1961 it was producing 1800 tons of lead ore per day. Its lifetime production is estimated at over 30,000,000 tons. At $5 a ton (average) that adds up to more than $125,000,000 from deep inside the bowels of the "Good Earth". Now the land and the industry on top, plus the will of her people to succeed is Bonne Terre's promising future.

END OF MINING

TODAY MARKS END OF MINING IN ST. FRANCOIS COUNTY

Friday, September 29, 1972

by Leroy Sigman

Without fanfare or ceremony an era that started with crude surface digging and evolved into the most productive lead mining operation in the world came to an end today as workers at the Federal Mill processed the last of the ore brought to the surface Thursday and St. Joe Minerals wrapped up productive mining operations in St. Francois County.

It might be considered somewhat ironic that while Missouri continues to be the leading producer of lead in the United States the area that once boasted the title of "Lead Capital of the World" no longer has a producing mine.

In a county where there have been more than a dozen mining companies at one time or another, the Federal Division of St. Joe Minerals is officially closed as of midnight Saturday, with only salvage and machine shop operations to continue.

Adding to the irony is that machine shop operations at Bonne Terre and two Flat River locations as well as general management operations out of Bonne Terre, will continue to serve the world's most productive lead mining functions, now to the west and southwest of what is fast becoming known as the "old Lead Belt".

Machine shop operations are expected to go on in the county for about another 14 to 16 months. Salvage operations are to be wrapped up in about 18 months. Management headquarters will be shifted sometime in 1975. Then all that will remain will be chat dumps, a tourist attraction in the old Bonne Terre Mine and the Lead Belt Mineral Museum.

Virtually every history book written about Missouri has called lead mining the first major attraction for settlers in the state, ranking with trapping and Indian trading.

For Nostalgia's sake one might review on this day the history of an industry that put this area on the map and is now, for practical purposes, just a matter of history.

It was in 1715 that the Governor of Louisiana, Antoinne de la Motte Cadillac, brought an exploration party into the northern part of what is now Madison County to see for himself the great mineral wealth he had been told existed.

While it was sometime later that the first major mining operation was launched by Phillippe Renault at that same site, now Mine La Motte, there were scattered and crude mining developments in Madison and Washington counties through much of the 18th century. In addition to the fur trading, the river shipment of ore from these sites and supplies to them was a key factor in the development of Ste. Genevieve.

In 1957 Desloge was closed and that original mining site of two centuries back, Mine La Motte, produced its last ore. In 1961 the Bonne Terre Mine was shut down and in 1963 Leadwood closed.

Instead came the new mining operations of Indian Creek, Fletcher, Viburnum, and now Brushy Creek have become the centers of St. Joe Minerals Company successor (and virtually the same firm) to St. Joseph Lead Company operations.

This history has been one of skimming over two centuries. It has been centered on St. Joe operations, but there are others that should be remembered, such as Desloge Consolidated Lead Company, Flat River Lead Company, National Lead Company, Doe Run Lead Company, Central Lead Company, Theodore Lead Company and others that did not even make the history books.

The story can be spiced with tidbits like the observation of an 18th century visitor who observed the hardworking French miner almost grimy beyond recognition on Saturday and dressed in the finest frills on Sunday. The protest that came when the Post Office Department named a new mining community Owl Creek. The protest was strong enough to get the name changed to Leadwood.

There is a great deal that can be said, but today is the end and what more should be said about lead mining in St. Francois County at this point? One community leader had this to say: "It is not the end of our progress — but that is another story that is still developing."

July 10, 1936

St. Joe Lead Company Buys Local National Mines

Now Owns Practically All of the St. Francois County Lead District

The St. Joseph Lead Company on Tuesday announced the purchase as of July 1st of all of the holdings in St. Francois County of the National Lead Company and embraces the original property and plant at St. Francois, the Pimmine and the Boston-Elvins property, a total of about 2000 acres.

Thus ends definitely the operation of what has been known as the National in St. Francois County. This Company entered the St. Francois County District in 1897, having purchased the W. R. Taylor property of 640 acres, which had been partially developed, at St. Francois. New shafts were sunk, a mill erected and actual mining operations begun a short while thereafter. The concentrates produced at the St. Francois plant were smelted at a plant erected at Collinsville, Illinois. Additional adjacent land was purchased until the property at St. Francois embraced between 1200 and 1300 acres. Later the Pim tract of 640 acres, a few miles south of Elvins, was purchased and a shaft sunk and a town built which was called Pimville. Still later the partially developed Boston-Elvins property of 40 acres, near Elvins, was bought. These three tracts composed the holdings of the National in St. Francois County, which has now become the property of the St. Joseph Lead Company.

Active mining operations by the National Company in this county were discontinued on February 28, 1933, because the condition of the lead market made it unprofitable to mine the low grade ore remaining on the National property.

The National still has extensive holdings in Madison and Washington counties. It is also jointly interested with the St. Joseph Company in property at Mine La Motte. It also owns and operates the National Pigments and Chemical Company in Washington County.

The price paid by the St. Joseph Lead Company for the National property in St. Francois County was not announced. It was stated, however, that early resumption of mining operations of the property was not contemplated. The purchase of the National now makes the St. Joseph Company owner of all the developed mining properties in the County. It purchased the Federal Lead Company several years ago and a few years ago bought the Desloge Consolidated Lead Company. The Doe Run Lead Company, a subsidiary of the St. Joseph Company, was dissolved last year. Four other companies which formerly operated in the District and whose property is now owned by the St. Joseph Company were the Central Lead Company, Columbia Lead Company, Derby Lead Company and Baker Lead Company.

prairies of tall grass "like a wheat field". Our streams were deeper and sand, far more navigable than today. Along them were deer, bear anc ducks and wild geese were plentiful. At certain seasons wild pigeons ca in one flock they blackened out the sun and broke down trees when settling to roost; here also was a beautiful species of parrot–each of these birds are now extinct. Early Ste. Genevieve Frenchmen lived well from our forests and also became wealthy fur traders.

Before the close of the 18th Century, Americans began coming over from Kentucky and Tennessee, Anglo-Saxtons with a mingling of Germans. First of these settlements is thought to be near Bonne Terre at Big River Mills, in St. Francois County. The Americans were bent on farming rather than mining and Big River Mills attracted a handful of these hardy pioneers back in 1794. By 1798, the Murphy's were staking off land to settle at what is now Farmington. In the vicinity of Bonne Terre and Farmington, therefore, are two of the county's oldest settlements dating back more than 150 years.

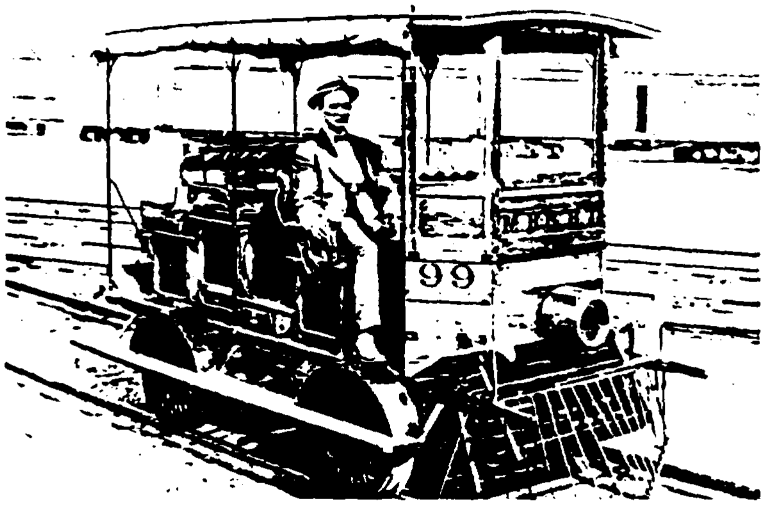
Our roads, however, far outdate our communities. The Bonne Terre-Old Mines trail is the oldest public highway in the county, more than 200 years old, it was extensively employed to bring lead ore out of the region to the Mississippi landing at Ste. Genevieve. Running from north to south this side of French Village is the Old St. Louis road which some historians claim to be the original El Camino Real, or Kingshighway, if so, it is the oldest thoroughfare in Missouri having its beginning no one knows when–the El Camino Real was originally an Indian trail and doubtless, before the Red Man, a path carved out of the forests by migrating animals (most of America's roads and highways follow buffalo trails, believe it or not).

Sid Long and Team

As has been pointed out, this township is the oldest settled in St. Francois but it was slow in getting a start. By 1860, there were no more than a half a dozen families residing at what is now Bonne Terre. At that time, La Grave owned the townsite, having purchased it from the Pratte brothers who came into the area in 1800 on a Spanish grant.

A mining prospector from Iron Mountain bought out La Grave's interest for $80,000 at the onset of the Civil War, the St. Joseph Lead Co., was formed and the mineral resources of Southeast Missouri first took on a semblance of big industry. Bonne Terre grew rapidly with outlying suburbs of Settletown, Bogytown, Moontown, Hilltown, Prattetown and Elvinstown.

But we are getting a mite ahead of our St. Francois County history. In the mid 1800's, transportation was slow and oft times impossible, especially during bad weather the heavy lumbering wagons pulled by oxen or horses bogged down in the deep binding mire, sometimes requiring a week or more to reach Ste. Genevieve from this county. Meanwhile large deposits of iron ore had been discovered at Iron Mountain and Pilot Knob, it was considered feasible to construct a plank road of heavy lumber, this road went through the county near Farmington and speeded the transports from Pilot Knob to the Mississippi. Hardened drivers could make the trip in two days by oxen. This was a toll road, still, due to the heavy wagons and their loads, the constant washouts and other destructive force of the elements, the plank road was a failure and the Southeast hailed the pushing through of the Iron Mountain Railroad in 1858. Shipments of our ore immediately shifted from the east to the west, leaving Ste. Genevieve stranded and a quaint memory to 20th Century historians to probe around in, a town that had a chance to become bigger than St. Louis had it not clung to its set old-fashioned ways.



T. V. Young, Superintendent M.R. & B.T.

In 1890, almost 100 years since the first settlement in the county the M. R. & B. T. Railroad came through, opening up our Lead Belt further and, 50 years later a paved (61-67) U. S. Highway came our way almost destroying the practibility of railroads. Now, again, come the aeroplanes, and doubtless another form of transportation when the Atomic Age gets under way.

The Hildebrands were among the earliest of St. Francois County settlers. They were shrewd Germans, uneducated as there were no schools when they arrived on the scene. They first came to an area in what is now Jefferson County and were first settlers of Jefferson; the Indians ran them back to Ste. Genevieve where they stayed, but a short time before striking out for the hinterlands again, this time toeing in on Big River outside of Bonne Terre. The exploits of two boys, Sam and Frank, culminated in a Vigilante Committee running the Hildebrands out of St. Francois County. Steeped in legend, Sam Hildebrand is as endeared in the country as Jesse James is in President Truman's country.

Back through the hills of St. Francois are remaining log cabins built when Moses Austin was the

OUR LEAD BELT HERITAGE

By Henry C. Thompson

-1992-

solidation. To all intent and purpose, the two companies were operated as one. Doe Run had a mill larger than was necessary for their holdings. On the other hand, St. Joe had their smelter and the consolidation of the two operations would make for economy in many ways. One minority stockholder and later a second one filed suit in an attempt to prevent consolidation. This suit dragged through the courts until 1936, but for those twenty years, separate books were kept for each of the two operations. Doe Run owed some four million dollars in 1913 while St. Joe owed about three million more. It was at that critical period that Clinton H. Crane was elected president of the two companies.

Chance plays curious tricks on occasions, and Crane was the victim of the chance circumstanace that pushed him into the presidency of a mining venture on pretty shaky grounds. His training had been as a nautical engineer. The problems that confronted him were terrific. Technological progress in mining, milling and smelting had outstripped adaptation by his companies. The seven million dollar debt was a serious concern, particularly since a good part of this was payable in a year and a half. How he succeeded is a long technical story and will not be detailed here.

FLOTATION PROCESS DISCOVERED —

Let's leave the district for a while and go out to Silver City, Colorado where a lady, whose husband worked in the mines there, was washing out some of his greasy and ore-laden work clothes. Mrs. Carrie Elverson was herself reported to have been a trained mining engineer. Whether she was sor not, is immaterial to this story.

Mrs. Elverson had noticed for some time that some heavy particles of mineral that were on the work clothes, were floating on the top of her wash water and that the particles of rock would sink to the bottom of her tub.

Pondering over this circumstance, she mentioned it to her husband and they set up an experimental tub and brought some finely ground ore and in a tub with highly saponified water and stirred the mass and found that the fine mineral particles floated up to the surface while the rock particles sank to the bottom, as they had done in her wash tub. This chance discovery, after many years of development and more years of litigation, turned out to be revolutionary and the greatest advance in ore dressing in many years.

Of course, this was the answer to the great loss of metal in the finely ground ores of this district. By 1914, by valiant effort, this process was installed in all of the mines of this district. St. Joe had all of their mills equipped with the flotation machines and with the expenditure of some sixty thousand dollars in equipment, they realized an additional income of nearly twenty thousand dollars per month.

With the dilemma of losing all of the finely ground galena removed, it was apparent that more of the ore should be finely ground to get at the small particles of galena entrapped in the rock. This has been the tendency in recent years. The jaw crushers were replaced with large gyratory crushers the rolls were made bigger and the jigs were replaced with Rod Mills. The percussion table has been immensely improved. All of this, with the flotation machines, has made it possible to recover a high percentage of the galena in the rock ore.

REMILLING THE CHATS —

After many years of mining and depreciating the ore reserves on the books of the company, part of the depreciated ore was found to be lying on the surface in the discarded jig chats.

Partly due to the prevailing high prices and improved milling methods, it was found profitable to haul part of this chat into the mills and run it through, in order to recover the mineral content that had been thrown away years ago.

The loading and hauling to the mills was found to be only a fraction of the cost of mining, hoisting and crushing which are necessary parts in processing newly mined ore. Consequently, it was found that a good return could be made by reworking these old chats and a substantial addition was made to the tonnages of concentrates sent to the smelter.

The Desloge mill was changed so as to operate exclusively on these reclaimed chats and the miners from Desloge were transferred to other work during 1947. Provisions were made at Bonne Terre, Leadwood and Federal to handle chats in addition to their regularly mined ore.

REFINEMENTS IN SMELTING —

Galena, as it is found in our Lead Belt mines is primarily a sulphide of lead. To reduce it to its metallic state, the sulphur must be first driven off and then melted down to metal.

In the days of the log and ash furnaces, this entire process was accomplished in one operation. A considerable portion of the metal was vaporized and lost forever, while some of the precious metal was lost by being mixed with the ashes from the fires used to reduce the ore.

When Moses Austin came to the district and erected his reverberatory furnace which kept the ore and fuel apart, a considerable saving was made and it was not long until this type of furnace made all others obsolete. The use of blast furnaces made further economies in smelting but again much of the finer particles of lead and the vaporized portions went up the stack. It was found that by making a condensing chamber at the base of each stack from the furnaces, much volatile material was saved. Simple, Eh? But by the end of 1889, it was estimated that twenty-five pigs of lead per day were saved and this amounted to about fifteen thousand dollars per year, at the prices that lead was selling for them.

It takes much less heat to drive off the sulphur from the galena, than is required to melt the lead, so somewhere along the line, somebody thought up the use of a roasting furnace. We have previously described the "Calcine" furnaces at Bonne Terre and elsewhere. After the smelter was moved to Herculaneum, the ore was roasted at the mines and the "sintered" product was shipped there for smelting. Wood was used as fuel to roast the ore until the railroad allowed "stone-coal" to be brought in. Six men were required to man each calcine but this pre-roasting was a material saving in fuel over the previous processes.

Looking back over the years and the developments in smelting, milling and mining, it is easy to say, "Why didn't someone think of those things before". The operating processes were continuous and when a new idea was presented, it was not always assured that it would be successful. Theory and practice are not always synonymous. The crucial test was - will it pay by lowering costs? Some schemes were tried and failed to make the savings anticipated, but those we enumerate were the ones that paid off.

About 1908, a most clever scheme was evolved in Europe, that someone should have thought of before. This Salverson process was to make a material saving in the cost of roasting the ore. St. Joe immediately sought and secured the patent rights in the United States.

Instead of building a fire under the ore and having men turn it over again and again to expose each particle of the ore to the heat, the idea was simply to put the ore into a large kettle or converter and by proper kindling, the sulphur burned itself out of the ore. Fifteen converters were built at Herculaneum in 1908 and fourteen more in 1909. The Salverson process saved a large percentage of smelting costs by saving man-power and fuel.

Costs and efficiency during 1911 were not in line with other smelters in other parts of the United States and Arthur S. Dwight was hired to study the processes and make recommendations so that the lead recovery might be brought to the highest possible point.

In the Salverson process, the ore had to be shoveled into the kettles and after it had burned itself out of sulphur, it had to be shoveled out again. One of Dwight's brilliant ideas was, why not make the process of burning the sulphur out of the ore into a continuous process? His idea was to have the concentrates fall out of the bins onto a long, continuously moving conveyor and would then fall into steel cars and move direct to the blast furnace bins. Here was really a step toward automation, but that term had not been heard of in that day.

All of these steps went far toward solving the smelting problem but much of the finer material and the flue gasses still went up the stack that had been built in 1919 to three hundred and fifty feet high, with the anticipation that the gasses would cool and the fine material drop back into the receiver at the base of the stack. It didn't work that way. The draft carried the fines up and out of the top of the stack.

Dwight's next proposal was to build a long flue system or trail, in which the gasses had a chance to cool and precipitate before they got to the stack. He also proposed a "bag-house" in which were literally hundreds of cotton bags through which the flue gasses passed on their way to the stack and were filtered and the dust fell into the bins at the bottom of the bag-house. The three hundred and fifty foot stack furnished the draft to move the gasses through this complicated system.

One thing remained to be done. There are from one to two ounces of silver in each ton of concentrates that must be removed. Not for the value of the silver but to make softer lead. Soft or de-silverized lead brings a higher

Third Edition

GLOSSARY OF GEOLOGY

Robert L. Bates and
Julia A. Jackson, Editors

American Geological Institute
Alexandria, Virginia
1987

angle of repose.

angle of ultimate stability *critical slope angle.*

anglesite (an'-gle-site) A white orthorhombic mineral: $PbSO_4$. It is a common secondary mineral formed by the oxidation of galena and is a valuable ore of lead. Syn: *lead vitriol; lead spar.*

angrite (an'-grite) An achondritic stony meteorite consisting chiefly of purple titaniferous augite (more than 90%) with a little olivine and troilite.

anguclast (an'-gu-clast) An angular *phenoclast,* such as a large fragment of a breccia. Cf: *spheroclast.*

angular (an'-gu-lar) Having sharp angles or borders; specif. said of a sedimentary particle showing very little or no evidence of abrasion, with all of its edges and corners sharp, such as blocks with numerous (15-30) secondary corners and a roundness value between zero and 0.15 (midpoint at 0.125) (Pettijohn, 1957, p. 58-59). Powers (1953) gives values between 0.17 and 0.25 (midpoint at 0.21). Also, said of the *roundness class* containing angular particles.

angular cross-bedding Cross-bedding in which the inclined beds appear in section as nearly straight lines meeting the underlying surface at high, sharp, or discordant angles; it often implies deposition by water, as in *torrential cross-bedding.* Cf: *tangential cross-bedding.*

angular discordance *angular unconformity.*

angular distance The angle, measured at the Earth's center, that subtends the great-circle path between the earthquake's epicenter and the receiver. Cf: *epicentral distance.*

angular distortion The change in shape of an area on a globe when it is represented on a map projection. See also: *distortion [cart].*

angular drift "Rock debris formed by intensive frost action, derived from underlying or adjacent bedrock" (ADTIC, 1955, p.4).

angular field of view The angle subtended by lines from a remote sensing system to the outer margins of the strip of terrain that is viewed by the system. Cf: *instantaneous field of view.*

angular fold A fold resembling a *kink fold* but with a less angular hinge.

angularity (an-gu-lar'-i-ty) A term often used for the property of a sedimentary particle now commonly known as *roundness,* but used by Lamar (1928, p. 148-151) for the property now referred to as *sphericity.*

angular spreading The lateral extension of ocean waves as they move out of the generating area as *swell.*

angular unconformity An *unconformity* between two groups of rocks whose bedding planes are not parallel or in which the older, underlying rocks dip at a different angle (usually steeper) than the younger, overlying strata; specif. an unconformity in which younger sediments rest upon the eroded surface of tilted or folded older rocks. It is sometimes regarded as a type of *nonconformity.* Cf: *discordance.* Syn: *angular discordance; clinounconformity; structural unconformity; orogenic unconformity.*

angulate drainage pattern (an'-gu-late) A modified *rectangular drainage pattern* developed where streams follow joints or faults that join each other at acute or obtuse angles, rather than at right angles (Zernitz, 1932, p. 517). Examples are found in the Timiskaming and Nipissing areas of Ontario.

anhedral (an-he'-dral) (a) Said of a mineral crystal that has failed to develop its own *rational faces* or that has a rounded or indeterminate form produced by the crowding of adjacent mineral grains during crystallization or recrystallization. (b) Said of a detrital grain that shows no crystal outline. (c) Said of the shape of such a crystal.—The term was originally used in reference to igneous-rock components by Cross et al. (1906, p. 698) in preference to the synonymous terms *xenomorphic* and *allotriomorphic* (as these were originally defined). Cf: *subhedral; euhedral.*

anhedron (an-he'-dron) Geometrical term for a solid figure not limited by plane surfaces. The term was introduced by Pirsson (1896) in reference to an imperfectly defined igneous-rock component (crystal). Pl: *anhedrons; anhedra.*

anhydrite (an-hy'-drite) A mineral consisting of anhydrous calcium sulfate: $CaSO_4$. It represents *gypsum* without its water of crystallization, and it alters readily to gypsum, from which it differs in crystal form (anhydrite is orthorhombic) and in being harder and slightly less soluble. Anhydrite usually occurs in white or slightly colored, granular to compact masses, forming large beds or seams in sedimentary rocks or associated with gypsum and halite in evaporites. Syn: *cube spar.*

anhydrock (an-hyd'-rock) A sedimentary rock composed chiefly of anhydrite.

anhydrous (an-hy'-drous) Said of a substance, e.g. magma or a mineral, that is completely or essentially without water. An anhydrous mineral contains no water in chemical combination.

anhysteretic remanent magnetization (an-hys'-ter-et'-ic) Remanent magnetization produced by simultaneous application of a constant magnetic field and an initially larger alternating magnetic field whose amplitude decreases smoothly to zero.

anideltoid (an-i-del'-toid) Externally visible anal deltoid, which is unaccompanied by any others and lies on the aboral side of the anal opening or the anispiracle (TIP, 1967, pt. S, p. 345).

anidiomorphic (an-id'-i-o-mor'-phic) *xenomorphic.*

anilite (an'-i-lite) A mineral: Cu_7S_4.

Animikean (A-nim'-i-ke'-an) Var. of *Animikie.*

Animikie (A-nim'-i-kie) A provincial series of the Proterozoic of the Canadian Shield; it is also called the *Animikean.*

animikite (a-nim'-i-kite) A silver ore consisting of a mixture of sulfides, arsenides, and antimonides showing striking intergrowth relations and occurring in white or gray granular masses. It contains nickel and lead. Cf: *macfarlanite.*

anion exchange (an'-i-on) The displacement of an anion bound to a site on the surface of a solid by an anion in solution. See also: *ion exchange.*

Anisian (A-ni'-sian) European stage: lower Middle Triassic (above Scythian, below Ladinian). Syn: *Virglorian.*

anisochela (an-i'-so-che'-la) A sponge *chela* having unequal or dissimilar ends. Cf: *isochela.*

anisodesmic (an-i'-so-des'-mic) Said of a crystal or compound in which the ionic bonds are of unequal strength. Cf: *isodesmic.*

anisomerism (an-i-som'-er-ism) (a) Repetition of parts that differ more or less importantly among themselves. (b) Reduction in number and differentiation of similar parts in organisms.

anisometric (an-i'-so-met'-ric) (a) Said of crystals having unequal dimensions, including those with a significant flattening (see *tabular*), elongation, or both. Ant: *equant; isometric.* (b) An obsolete syn. of *heterogranular.*

anisomyarian (an-i'-so-my-ar'-i-an) adj. Said of a mollusk with anterior adductor muscles much reduced or absent.—n. A mollusk with such muscles. Cf: *heteromyarian.*

anisotropic (an-i'-so-trop'-ic) Having some physical property that varies with direction. All crystals are anisotropic relative to some properties, e.g. propagation of sound waves. Unless otherwise stated, however, the term refers to optical properties. In this sense, all crystals except those of the isometric system are anisotopic. Ant: *isotropic.* Syn: *aeolotropic.*

anisotropy (an-i-sot'-ro-py) The condition of having different properties in different directions, as in geologic strata that transmit sound waves with different velocities in the vertical and horizontal directions. Adj: *anisotropic.*

anispiracle (an-i-spi'-ra-cle) An enlarged opening in the summit part of the posterior interray of a blastoid, formed by the union of anal opening and posterior spiracle or spiracles.

anitaxis (an-i-tax'-is) A linear succession of crinoid anal plates. Pl: *anitaxes.*

ankaramite (an-ka'-ra-mite) An olivine-bearing *basalt* containing numerous pyroxene and olivine phenocrysts, the former being more abundant than the latter, in a fine-grained groundmass composed of clinopyroxene microlites and calcic plagioclase. It was named by Lacroix in 1916 from Ankaramy, Malagasy.

ankaratrite (an-ka'-ra-trite) Olivine *nephelinite* containing biotite. Named by Lacroix in 1916 for Ankaratra, Malagasy. Not recommended usage.

ankerite (an'-ker-ite) A white, red, or grayish iron-rich mineral related to dolomite: $Ca(Fe,Mg,Mn)(CO_3)_2$. It is associated with iron ores and commonly forms thin veins of secondary matter in some coal seams. Syn: *ferroan dolomite; cleat spar.*

ankylosis (an-ky-lo'-sis) (a) Fusion of columnals or other skeletal elements of an echinoderm, commonly obscuring the sutures. (b) In vertebrates, comparable fusion between adjacent bones, or between base of tooth and supporting bone.—Also spelled: *anchylosis.*

annabergite (an'-na-berg-ite') An apple-green mineral: $(Ni,Co)_3(AsO_4)_2 \cdot 8H_2O$. It is isomorphous with erythrite, and usually occurs in incrustations as an alteration product of nickel arsenides. Syn: *nickel bloom; nickel ocher.*

annealing recrystallization (an-neal'-ing) The formation of new grains in a rock after solid-state deformation, while the temperature is still high. This is a recovery process, starting with nucleacurved, or coiled and is divided into chambers connected by a siphuncle; the shell is internal in present-day cephalopods and their fossil ancestors, such as the belemnites. Nautiloids and ammonoids are extinct cephalopods, generally valuable as index fossils; octopuses, squids, and cuttlefishes are common living cephalopods. Range, Cambrian to present.

cephalothorax (ceph'-a-lo-tho'-rax) The fused *head* and *thorax* of certain arthropods; e.g. the anterior part of the body of a crustacean, composed of united cephalic and thoracic somites and covered by the carapace, or the fore part of the body of a merostome in front of the opisthosoma, or the anterior part of the body of an arachnid, bearing six pairs of appendages. Cf: *prosoma; gnathothorax.*

cerargyrite (ce-rar'-gy-rite) (a) *chlorargyrite.* (b) A group name for isomorphous isometric silver halides, mainly chlorargyrite, bromargyrite, and embolite.—Also spelled: *kerargyrite.*

ceratite (cer'-a-tite) Any ammonoid belonging to the order Ceratitida, characterized by a shell having sutures with serrate lobes and, in some groups, by an ornamented shell. Range, Permian to Triassic.

ceratitic suture (ce-ra-tit'-ic) A type of suture in ammonoids characterized by small, rounded, unbroken saddles and finely denticulate lobes developed on a major set; specif. a suture in ceratites. Cf: *ammonitic suture; goniatitic suture; pseudoceratitic suture.*

ceratoid (cer'-a-toid) Said of a very slenderly conical, horn-shaped corallite of a solitary coral.

ceratolith (ce-rat'-o-lith) A horseshoe-shaped skeletal element of the coccolithophorid *Ceratolithus,* acting optically as a single unit of calcite.

cercopod (cer'-co-pod) *cercus.*

cercus (cer'-cus) Either of a pair of simple or segmented appendages situated at the posterior end of certain arthropods; e.g. a *caudal ramus* of a crustacean. Pl: *cerci.* Syn: *cercopod.*

ceresine (cer'-e-sine) A white wax that results from the bleaching of *ozocerite.*

cerianite (ce'-ri-an-ite') A mineral: CeO_2. It usually contains some thorium.

cerine (ce'-rine) (a) *allanite.* (b) *cerite.*

cerioid (cer'-i-oid) Said of a massive corallum in which the walls of adjacent polygonal corallites are closely united.

cerite (ce'-rite) A trigonal mineral: $(Ce,Ca)_9(Mg,Fe)Si_7(O,OH,F)_{28}$. Syn: *cerine.*

černýite A mineral occurring in pegmatites, intergrown with kesterite: Cu_2CdSnS_4.

cerolite (ce'-ro-lite) A yellow or greenish waxlike mixture of serpentine and stevensite.

cerotungstite (ce-ro-tung'-stite) A monoclinic mineral: $CeW_2O_6(OH)_3$.

Cerozem (Cer'-o-zem) *Sierozem.*

cerrito (cer-ri'-to) A small *cerro.* Syn: *cerrillo.*

cerro (cer'-ro) A term used in the SW U.S. for a hill, esp. a craggy or rocky eminence of moderate height. Etymol: Spanish.

ceruleite (ce-ru'-le-ite) A turquoise-blue mineral: $Cu_2Al_7(OH)_{13}(AsO_4)_4 \cdot 11.5H_2O$. Also spelled: *ceruléite.*

cerulene (ce'-ru-lene) (a) A trade name for a form of calcite colored blue or green by azurite or malachite and used as a gemstone. (b) A term used less correctly for a blue variety of satin spar.

cerussite (ce-rus'-site) A colorless, white, yellowish, or grayish orthorhombic mineral of the aragonite group: $PbCO_3$. It is a common alteration product of galena and is a valuable ore of lead. Syn: *white lead ore; lead spar.*

cervantite (cer-van'-tite) A white or yellow orthorhombic mineral: $Sb^{+3}Sb^{+5}O_4$. It was formerly regarded as identical with stibiconite.

cervical groove (cer'-vi-cal) In decapods, a transverse groove somewhat parallel to the postcervical groove and placed before it. It extends upward from the confluence of the hepatic and antennal grooves (Holthuis, 1974, p. 733).

cervical sinus An indentation at the front of the carapace of a cladoceran crustacean, exposing the rear part of the head.

cesanite (ce'-sa-nite) A mineral: $Ca_2Na_3[(OH)(SO_4)_3]$. It is isotypic with apatite.

cesarolite (ce-sa'-ro-lite) A steel-gray mineral: $H_2PbMn_3O_8$. It occurs in spongy masses.

cesbronite (ces-bron'-ite) A mineral: $Cu_5(TeO_3)_2(OH)_6 \cdot 2H_2O$.

cesium kupletskite (ce'-si-um) A mineral of the astrophyllite group: $(Cs,K,Na)_3(Mn,Fe)_7(Ti,Nb)_2Si_8O_{24}(O,OH,F)_7$. It forms a series with kupletskite.

cesium-vapor magnetometer (ce'-si-um-va'-por) A type of *optically pumped magnetometer* that measures the absolute total magnetic intensity with extreme sensitivity by determining the Larmor frequency of cesium atoms. Cf: *rubidium-vapor magnetometer.*

cestibtantite (ces-tib-tant'-ite) A mineral isostructural with microlite: $(Cs,Na)SbTa_4O_{12}$.

ceylonite (cey-lon'-ite) A dark green, brown, or black variety of spinel containing iron. Syn: *pleonaste; candite; ceylanite; zeylanite.*

cf. (a) Used in paleontology to indicate that a specimen is very closely comparable to, but not certainly the same as, those of a named species; it implies more certain similarity than does *aff.* (b) Used in this glossary and other reference works to mean "compare".—Etymol: Latin *conferre,* "to compare".

chabazite (chab'-a-zite) A zeolite mineral: $CaAl_2Si_4O_{12} \cdot 6H_2O$. It sometimes contains sodium and potassium. Also spelled: *chabasite.*

chabourneite (cha'-bourne-ite) A mineral: $Tl_{21-x}Pb_{2x}(Sb,As)_{91-x}S_{147}$; $x = 0$ to 17.15.

chadacryst (chad'-a-cryst) (a) The enclosed crystal in a poikilitic texture. (b) A syn. of *xenocryst.* —Also spelled: *cadacryst.*

Chadronian (Chad-ron'-i-an) North American continental stage: Lower Oligocene (above Duchesnean, below Orellan).

chaemolith (chae'-mo-lith) *humic coal.*

chaetetid (chae-tet'-id) Any organism characterized by massive coralla composed of very slender aseptate corallites with imperforate walls and complete tabulae. The chaetetids are currently placed in the tabulate-coral family Chaetetidae, but have been variously classified as hydrozoans, anthozoans, bryozoans, and sponges. Range, Ordovician to Permian.

chaff peat Peat that is derived from fragments of plants.

chagrenate (cha'-gre-nate) Said of a smooth and translucent sculpture of pollen and spores.

chain [geomorph] A general term for any series or sequence of related natural features arranged more or less longitudinally, such as a chain of lakes, islands, seamounts, or volcanoes; esp. a *mountain chain* or other extended group of more or less parallel features of high relief.

chain [ore dep] adj. In mineral deposits, e.g. chromite, said of a crystal texture or structure in which a series of connected crystals resembles a linked or chainlike pattern.

chain [surv] (a) A measuring device used in land surveying, consisting of 100 links joined together by rings; specif. *Gunter's chain.* The term is commonly used interchangeably with *tape* although strictly a chain is a series of links and a tape is a continuous strip. (b) A unit of length prescribed by law for the survey of U.S. public lands and equal to 66 feet or 4 rods. It is a convenient length for land measurement because 10 square chains equals one acre.

chain coral Any coral (esp. one belonging to the family Halysitidae) characterized, in plan view, by cylindrical, oval, or subpolygonal corallites joined together on two or three sides to form a branching, chainlike network.

chain crater One of several small aligned depressions on the surface of the Moon, Mars, and Mercury, believed to be formed by either volcanic activity or by secondary impacts; more commonly applied to those of probable volcanic origin. See also: *crater chain.*

chain gage A type of *gage* used in determining water-surface elevation, consisting of a tagged or indexed chain, tape, or other form of line. It is used in situations in which the water surface is difficult to reach. Cf: *staff gage.*

chaining (chain'-ing) A term that was applied originally to measuring distances on the ground by means of a surveyor's chain, but later to the use of either a chain or a surveyor's tape. The term was formerly synonymous with *taping,* but "chaining" is now preferred (for historical and legal reasons) for surveys of the U.S. public-lands system and "taping" for all other surveys.

chainman (chain'-man) A surveyor's assistant who measures distances, marks measuring points, and performs related duties; specif. one who marks the tape ends in chaining or who measures distances with a tape. See also: *rodman.* Syn: *tapeman.*

chain silicate *inosilicate.*

chalcanthite (chal-can'-thite) A blue triclinic mineral: $CuSO_4 \cdot 5H_2O$. It is a minor ore of copper. Syn: *blue vitriol; copper vitriol; bluestone; cyanosite.*

chalcedonic chert (chal-ce-don'-ic) A transparent, translucent, vitreous, milky, smoky, waxy, or greasy variety of *smooth chert,* generally buff or blue-gray, sometimes mottled (Ireland et al.,

G

Ga Billions of years before the present.

gabbride (gab'-bride) A term used in the field for any igneous rock having pyroxene as the only dark mineral, which forms over 50 percent of the rock, with a smaller amount of feldspar; e.g. augite *diorite, gabbro, norite.* Not recommended usage.

gabbro (gab'-bro) (a) In the *IUGS classification,* a plutonic rock with Q between 0 and 5, P/(A + P) greater than 90, and plagioclase more calcic than An_{50}. (b) A group of dark-colored, basic intrusive igneous rocks composed principally of basic plagioclase (commonly labradorite or bytownite) and clinopyroxene (augite), with or without olivine and orthopyroxene; also, any member of that group. It is the approximate intrusive equivalent of *basalt.* Apatite and magnetite or ilmenite are common accessory minerals. Gabbro grades into *monzonite* with increasing alkali-feldspar content. According to Streckeisen (1967, p. 171, 198), plagioclase with more than 50% anorthite distinguishes gabbro from *diorite;* quartz is 0-20% of the light-colored constituents, and the plagioclase/total feldspar ratio is 90/100.—The name, introduced by Buch in 1810, is apparently after the town of Gabbro in Tuscany, Italy.

gabbroic layer (gab-bro'-ic) *basaltic layer.*

gabbroid (gab'-broid) (a) In the *IUGS classification,* a preliminary term (for field use) for a plutonic rock with Q less than 20 or F less than 10, P/A + P) greater than 65, and pl/(pl + px + ol) between 10 and 90. Cf: *leucogabbroid; melagabbroid.* (b) Said of a rock resembling gabbro. (c) A nonpreferred syn. of *ophitic.*

gabbronorite (gab-bro-nor'-ite) In the *IUGS classification,* a plutonic rock satisfying the definition of *gabbro,* in which pl/(pl + px + ol) and pl/(pl + px + hbl) are between 10 and 90, and ol/(pl + px + ol) and hbl/(pl + px + hbl) are less than 5.

gabbrophyre (gab'-bro-phyre) A porphyritic hypabyssal rock composed of phenocrysts of labradorite and augite in a groundmass of calcic plagioclase and hornblende. Not recommended usage.

gabion (ga'-bi-on) A specially designed container, cylinder, or box of corrosion-resistant wire used to hold coarse rock aggregate, as in forming a groin or seawall, or to assist in developing a bar or dike in a harbor. Gabions are also often placed at the toe of slide-prone slopes to improve stability.

gabrielsonite (ga'-bri-el-son-ite') A mineral: $PbFe(AsO_4)(OH)$.

gadolinite (gad-o'-lin-ite) A black, greenish-black, or brown mineral: $Be_2FeY_2Si_2O_{10}$. It is a source of rare earths.

gagarinite (ga-ga'-rin-ite) A creamy, yellowish, or rosy hexagonal mineral: $NaCaY(F,Cl)_6$.

gagatite (ga'-ga-tite) Coalified woody material, resembling jet. See also: *gagatization.*

gagatization (ga'-ga-ti-za'-tion) In coal formation, the impregnation of wood fragments with dissolved organic substances. See also: *gagatite.*

gage n. In hydraulics, a device for measuring such factors as water-surface elevation, velocity of flow, water pressure, and precipitation. See also: *staff gage; chain gage.*

gage height *stage [hydraul].*

gageite (gage'-ite) A mineral: $(Mn,Mg,Zn)_7Si_2O_7(OH)_8$.

gaging (gag'-ing) *stream gaging.*

gaging station A particular site on a stream, canal, lake, or reservoir where systematic observations of gage height, discharge, or water quality (or any combination of these) are obtained.

gahnite (gahn'-ite) A dark-green to yellowish, gray, or black mineral of the spinel series: $ZnAl_2O_4$. It often contains some magnesium. Syn: *zinc spinel.*

gahnospinel (gahn'-o-spi-nel') A blue or greenish variety of spinel containing zinc.

gaidonnayite (gai-don-nay'-ite) An orthorhombic mineral: $Na_2ZrSi_3O_9 \cdot 2H_2O$. It is dimorphous with catapleiite.

gain control In a seismic amplifier, a device to change the amplification with time. It may be automatic by individual channel, ganged for all channels together, programmed prior to the shot, or otherwise pre-arranged. Syn: *volume control.*

gaining stream (gain'-ing) *effluent stream.*

gaitite (gait'-ite) A mineral, the Zn-analogue of talmessite: $H_2Ca_4Zn(AsO_4)_4(OH)_2$.

gaize A porous fine-grained micaceous glauconitic sandstone, containing much soluble silica, occurring among the Cretaceous rocks of France and Belgium; a calcareous clastic sediment cemented by chert or flint. See also: *opoka.*

gal A unit of acceleration, used in gravity measurements. One gal = 1 cm/sec² = 10^{-2}m/sec². The Earth's normal gravity is 980 gal. The term is not an abbreviation: it was invented to honor the memory of Galileo. See also: *milligal; microgal.*

galactic cluster (ga-lac'-tic) *star cluster.*

galactite (ga-lac'-tite) (a) A variety of white natrolite, occurring in colorless acicular crystals. (b) An obsolete syn. of *novaculite.* (c) An unidentified stone (possibly of calcium nitrate) whose milky solution gave rise to several medieval legends and superstitions.

galaxite (ga'-lax-ite) A black mineral of the spinel series: $MnAl_2O_4$. The manganese is often replaced in part by ferrous iron or magnesium, and the aluminum by ferric iron.

galaxy (gal'-ax-y) One of billions of large systems of stars, nebulae, star clusters, globular clusters, and interstellar matter that make up the Universe. When the term is capitalized, it refers to the Milky Way stellar system. Syn: *extragalactic nebula.*

galea (ga'-le-a) (a) A conical process in the skeleton of a phaeodarian radiolarian. (b) The spinning tube on the movable finger of the chelicera of certain arachnids (pseudoscorpions). (c) The outer distal hoodlike lobe of the second segment of the maxillule of a crustacean, adjacent to the *lacinia* (TIP, 1969, pt.R, p. 96).

Gale alidade A syn. of *explorer's alidade.* Named for Hoyt S. Gale (1876-1952), American geologist.

galeite (gale'-ite) A trigonal mineral: $Na_{15}(SO_4)_5F_4Cl$. Cf: *schairerite.*

galena (ga-le'-na) A bluish-gray to lead-gray mineral: PbS. It frequently contains included silver minerals. Galena occurs in cubic or octahedral crystals, in masses, or in coarse or fine grains; it is often associated with sphalerite as disseminations in veins in limestone, dolomite, and sandstone. It has a shiny metallic luster, exhibits highly perfect cubic cleavage, and is relatively soft and very heavy. Galena is the most important ore of lead and one of the most important sources of silver. Syn: *galenite; lead glance; blue lead.*

galenite (ga-len'-ite) *galena.*

galenobismutite (ga-le'-no-bis'-mut-ite) A lead-gray or tin-white mineral: $PbBi_2S_4$.

galkhaite (gal'-kha-ite) A cubic mineral: $(Hg,Cu,Zn)(As,Sb)S_2$.

gall [sed] (a) *clay gall.* (b) A sand pipe.

gall [soil] A small barren or infertile surface spot or area from which the original surface soil has been removed by erosion or excavation.

gallery [grd wat] (gal'-ler-y) *infiltration gallery.*

gallery [paleont] A laterally continuous internal open space between adjacent laminae in most stromatoporoid coenostea, partially filled by pillars and dissepiments.

gallery [speleo] A large, more or less horizontal passage in a cave.

galliard (gal'-liard) A hard, smooth, close-grained, siliceous sandstone; a *ganister.* Also spelled: *calliard.*

gallite (gal'-lite) A tetragonal mineral: $CuGaS_2$.

galloping glacier (gal'-lop-ing) A popular term for *surging glacier.*

Gall projection A stereographic, modified-cylindrical map projection in which the cylinder intersects the globe along the parallels from 1814.

pyrometamorphism (py'-ro-met'-a-mor'-phism) Metamorphic changes taking place without the action of pressure or water vapor, at temperatures near the melting points of the component minerals; it is a local, intense type of *thermal metamorphism*, resulting from the unusually high temperatures at the contact of a rock with magma, e.g. in xenoliths (Turner, 1948). Cf: *igneous metamorphism*.

pyrometasomatic (py'-ro-met'-a-so-mat'-ic) Formed by *metasomatic* changes in rocks, principally in limestone, at or near intrusive contacts, under influence of magmatic emanations and high temperature and pressure.

pyrometasomatism (py'-ro-met'-a-som'-a-tism) The formation of contact-metamorphic mineral deposits at high temperatures by emanations issuing from the intrusive and involving replacement of enclosing rock with addition or subtraction of materials; *skarn* formation. See also: *metasomatism*.

pyrometer (py-rom'-e-ter) An instrument that measures high temperature, e.g. of molten lavas, by electrical or optical means. See also: *optical pyrometer; pyrometry*.

pyrometric cone (py-ro-met'-ric) *Seger cone*.

pyrometry (py-rom'-e-try) The measurement of high temperatures by electrical or optical means, using a *pyrometer*. Its geologic application is to incandescent lavas.

pyromorphite (py-ro-mor'-phite) A green, yellow, brown, gray, or white mineral of the apatite group: $Pb_5(PO_4)_3Cl$. It is isomorphous with mimetite and vanadinite, and may contain arsenic or calcium. Pyromorphite is found in the oxidized zone of lead deposits, and is a minor ore of lead. Syn: *green lead ore*.

pyrope (py'-rope) (a) The magnesium-aluminum end-member of the garnet group, characterized by a deep fiery-red color: $(Mg,Fe)_3Al_2(SiO_4)_3$. It rarely occurs in crystals, but is found in detrital deposits as rounded and angular fragments, or associated with olivine and serpentine in basic igneous rocks such as kimberlite. See also: *Cape ruby; Bohemian garnet*. Syn: *rock ruby*. (b) An obsolete name for a bright red gem, such as a ruby.

pyrophane (py'-ro-phane) (a) *fire opal*. (b) An opal (such as hydrophane) artificially impregnated with melted wax.

pyrophanite (py-roph'-a-nite) A blood-red mineral: $MnTiO_3$. It is isomorphous with ilmenite.

pyrophyllite (py-roph'-yl-lite) A white, gray, or brown mineral: $Al_2Si_4O_{10}(OH)_2$. It resembles talc and occurs in a foliated form or in compact masses in quartz veins, granites, and esp. metamorphic rocks. Syn: *pencil stone*.

pyropissite (py-ro-pis'-site) An earthy, nonasphaltic pyrobitumen made up primarily of water, humic acid, wax (it is a source of *montan wax*), and silica. It is frequently found associated with *brown coal*, which is then called pyropissitic brown coal.

pyroretinite (py-ro-ret'-i-nite) A type of retinite found in the brown coals of Aussig (Usti nad Labem), Bohemian Czechoslovakia.

pyroschist (py-ro-schist') A schist or shale that has a sufficiently high carbon content to burn with a bright flame, or to yield volatile hydrocarbons, when heated.

pyrosmalite (py-ros'-ma-lite) A colorless, pale-brown, gray, or grayish-green mineral: $(Fe^{+2},Mn)_8Si_6O_{15}(OH,Cl)_{10}$. Cf: *manganpyrosmalite*.

pyrosphere (py'-ro-sphere) The zone of the Earth below the lithosphere, probably partly molten; it is equivalent to the *barysphere*. Syn: *magmosphere*.

pyrostibite (py-ro-stib'-ite) *kermesite*.

pyrostilpnite (py-ro-stilp'-nite) A hyacinth-red monoclinic mineral: Ag_3SbS_3. It is polymorphous with pyrargyrite. Syn: *fireblende*.

pyroxene (py'-rox-ene, py-rox'-ene) (a) A group of dark rock-forming silicate minerals, closely related in crystal form and composition and having the general formula: $ABSi_2O_6$, where A = Ca, Na, Mg, or Fe^{+2}, and B = Mg, Fe^{+2}, Fe^{+3}, Fe, Cr, Mn, or Al, with silicon sometimes replaced in part by aluminum. It is characterized by a single chain of tetrahedra with a silicon:oxygen ratio of 1:3; by short, stout prismatic crystals; and by good prismatic cleavage in two directions parallel to the crystal faces and intersecting at angles of about 87° and 93°. Colors range from white to dark green or black. Pyroxenes may crystallize in the orthorhombic or monoclinic systems; they constitute a common constituent of igneous rocks, and are similar in chemical composition to the amphiboles (except that the pyroxenes lack hydroxyls). (b) A mineral of the pyroxene group, such as enstatite, hypersthene, diopside, hedenbergite, acmite, jadeite, pigeonite, and esp. augite.—Etymol: Greek *pyros*, "fire", + *xenos*, "stranger", apparently so named from the mistaken belief that the pyroxenes "were only accidentally caught up in the lavas that contain them" (Challinor, 1978, p. 250). Pron: *pie*-rok-seen or *peer*-ok-seen.

pyroxene alkali syenite In Tobi's classification of the *charnockite series* (1971, p. 202), a member with less than 20% quartz and characterized by the presence of microperthite.

pyroxene-hornblende gabbronorite (py'-rox-ene-horn'-blende) In the *IUGS classification*, a plutonic rock satisfying the definition of *gabbro* in which pl/(pl + hbl + px) is between 10 and 90, and px/(pl + hbl + px) and hbl/(pl + hbl + px) are greater than 5.

pyroxene-hornblende peridotite In the *IUGS classification*, a plutonic rock with M equal to or greater than 90, ol/(ol + hbl + px) between 40 and 90, px/(ol + hbl + px) greater than 5, and hbl/(ol + hbl + px) greater than 5.

pyroxene hornblendite In the *IUGS classification*, a plutonic rock with M equal to or greater than 90, ol/(ol + hbl + px) less than 5, and hbl/(px + hbl) between 50 and 90.

pyroxene-hornfels facies (py'-rox-ene-horn'-fels) The set of metamorphic mineral assemblages (facies) in which basic rocks are represented by diopside + hypersthene + plagioclase, with amphibole typically absent. Pelitic assemblages exhibit the association of sillimanite (or andalusite) and cordierite with potassium feldspar; muscovite is absent and biotite usually small in amount. Marbles should ideally contain wollastonite and calcite + forsterite + periclase (Turner, 1968). The facies is typical of high-grade thermal metamorphism, as in the inner parts of contact aureoles. It corresponds to temperatures in excess of about 550°C, and to relatively low pressures.

pyroxene monzonite In Tobi's classification of the *charnockite series* (1971, p. 202), a quartz-poor member containing approximately equal amounts of microperthite and plagioclase; *mangerite*.

pyroxene peridotite In the *IUGS classification*, a plutonic rock with M equal to or greater than 90, ol/(ol + hbl + px) between 40 and 90, and hbl/(ol + hbl + px) less than 5.

pyroxene-perthite (py'-rox-ene-perth'-ite) Lamellar intergrowths of any of several pyroxenes, as with the feldspars.

pyroxene syenite In Tobi's classification of the *charnockite series* (1971, p. 202), a quartz-poor member having more microperthite than plagioclase; a *mangerite-syenite*.

pyroxenide (py-rox'-e-nide) An informal term, used in the field, for any holocrystalline, medium- to coarse-grained igneous rock composed chiefly of pyroxene; e.g. a pyroxenite (Johannsen, 1931).

pyroxenite (py-rox'-e-nite) (a) In the *IUGS classification*, a plutonic rock with M equal to or greater than 90 and ol/(ol + opx + cpx) less than 40. (b) An ultramafic plutonic rock chiefly composed of pyroxene, with accessory hornblende, biotite, or olivine. Syn: *pyroxenolite*.

pyroxenoid (py-rox'-e-noid) Any mineral chemically analogous to pyroxene but with the SiO_4-tetrahedra connected in chains with a repeat unit of 3, 5, 7, or 9; e.g. wollastonite and rhodonite.

pyroxenolite (py-ro-xen'-o-lite) A term proposed by Lacroix in 1894 as a synonym for *pyroxenite* of English-speaking petrologists, as the French usage of *pyroxenite* was confined to metamorphic rocks. Not recommended usage.

pyroxferroite (py-rox-fer'-ro-ite) A yellow mineral of the pyroxenoid group found in Apollo 11 lunar samples: $(Fe,Mn,Ca)SiO_3$. It is the iron analogue of pyroxmangite.

pyroxmangite (py-rox-man'-gite) A red or brown triclinic mineral of the pyroxenoid group: $(Mn,Fe,Ca,Mg)SiO_3$.

pyrrhite (pyr'-rhite) *pyrochlore*.

pyrrhotine (pyr'-rho-tine) *pyrrhotite*.

pyrrhotite (pyr'-rho-tite) A common red-brown to bronze pseudohexagonal mineral: $Fe_{1-x}S$. It has a defect structure in which some of the ferrous ions are lacking. Some pyrrhotite is magnetic. The mineral is darker and softer than pyrite; it is usually found massive and commonly associated with pentlandite, often containing as much as 5% nickel, in which case it is mined as an ore of nickel. Syn: *pyrrhotine; magnetic pyrites; dipyrite*.

pythmic (pyth'-mic) Pertaining to the bottom of a lake (Klugh, 1923, p.372).

A Comprehensive Guide to the Hazardous Properties of Chemical Substances

Pradyot Patnaik, Ph.D.

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TABLE 34.1 **Maximum Concentration of Metal Contaminants for Toxicity Characteristics**

Metal	CAS No.	Regulatory Level (mg/L)
Arsenic	[7440-38-2]	5.0
Barium	[7440-39-3]	100.0
Cadmium	[7440-43-9]	1.0
Chromium	[7440-47-3]	5.0
Lead	[7439-92-1]	5.0
Mercury	[7439-97-6]	0.2
Selenium	[7482-49-2]	1.0
Silver	[7440-22-4]	5.0

environment. The toxicity of these metals is discussed in the following sections; zinc is discussed in Chapter 33.

34.2 LEAD

Symbol Pb; at. wt. 207.2; at. no. 82; valences 2, 4; CAS [7439-92-1]

Uses and Exposure Risk

Lead has been known to humankind since ancient times. It is a major component of many alloys, such as bronze and solder. It is used for tank linings, piping, and building construction; in the manufacture of pigments for paints, tetraethyllead, and many organic and inorganic compounds; in storage batteries; and in ceramics.

Physical Properties

Silvery gray metal; lustrous when freshly cut, loses its shine when exposed to air; soft; resistant to corrosion; opacity to gamma and x-rays; mp 327.5°C; bp 1740°C; density 11.35 at 20°C; reacts with hot concentrated nitric, hydrochloric, and sulfuric acids; resistant to hydrofluoric acid and brine.

Health Hazard

Toxic routes of exposure to lead are food, water, and air. It is an acute as well as a chronic toxicant. The toxic effects depend on the dose and the nature of the lead salt. Ingestion of lead paint chips is a common cause of lead poisoning among children. Chronic toxic effects may arise from occupational exposure.

Acute toxic symptoms include ataxia, repeated vomiting, headache, stupor, hallucinations, tremors, convulsions, and coma. Such symptoms are manifested by the encephalopathic syndrome. Chronic exposure can cause weight loss, central nervous system effects, anemia, and damage to the kidney. Chronic lead poisoning adversely affects the central and peripheral nervous systems, causing restlessness, irritability, and memory loss. Permanent brain damage has been noted among children from lead poisoning. Kidney damage arising from short-term ingestion of lead is reversible; while a longer-term effect may develop to general degradation of the kidney, causing glomular atrophy, interstitial fibrosis, and sclerosis of vessels (Manahan 1989). Inhalation of lead dusts can cause gastritis and changes in the liver. Lead is significantly bioaccumulated in bones and teeth, where it is stored and released. It binds to a number of cellular ligands, interfering with some calcium-regulated functions. Lead has an affinity for sulfhydryl groups (—SH), which are present in many enzymes. Thus it inhibits enzymatic activity. One such effect is the inhibition of δ-aminolevulinic acid dehydratase, an enzyme required for the biosynthesis of heme, an iron(II)–porphyrin complex in hemoglobin and cytochrome.

Carcinogenicity of lead has not been observed in humans; the evidence in animals is inadequate.

Exposure Limits

TLV-TWA 0.15 mg/m^3 as Pb (ACGIH and MSHA), 0.05 mg (Pb)/m^3 (OSHA); 10-hr TWA 0.1 mg(inorganic lead)/m^3 (NIOSH).

34.3 CADMIUM

Symbol Cd; at. wt. 112.4; at. no. 48; valence 2; CAS [7440-43-9]; a Group IIB element in the periodic table

Uses and Exposure Risk

Cadmium is used in electroplating, in nickel–cadmium storage batteries, as a coating for other metals, in bearing and low-melting alloys, and as control rods in nuclear reactors. Cadmium compounds have numerous applications, including dyeing and printing textiles, as TV phosphors, as pigments and enamels, and in semiconductors and solar cells.

Physical Properties

Bluish-white metal; malleable; density 8.64 at 20°C; mp 321°C; bp 767°C; vapor pressure 0.095 torr at 321°C; vapor pressure of solid at room temperature produces 0.12 mg/m³ of Cd; soluble in acids.

Health Hazard

There are several reports of cadmium poisoning and human death. Cadmium can enter the body by inhalation of its dusts or fumes, or by ingestion. In humans the acute toxic symptoms are nausea, vomiting, diarrhea, headache, abdominal pain, muscular ache, salivation, and shock. In addition, inhalation of its fumes or dusts can cause cough, tightness of chest, respiratory distress, congestion in lungs, and bronchopneumonia. A 30-minute exposure to about 50 mg/m³ of its fumes or dusts can be fatal to humans. The oral LD_{50} value in rats is in the range 250 mg/kg.

Cadmium is a poison that is accumulated in the liver and kidneys. Thus chronic poisoning leads to liver and kidney damage. Its biological half-life in humans is estimated at about 20–30 years (Manahan 1989). Cigarette smoking and calcium-deficient diet enhance its toxicity. The absorption of this metal through the gastrointestinal tract is low.

Cadmium is also known to produce the so-called "itai, itai" disease, which is a bone disease together with kidney malfunction.

Cadmium, similar to other heavy metals, binds to the sulfhydryl (—SH) groups in enzymes, thus inhibiting enzymatic activity.

Intramuscular administration of cadmium produced tumors in the lungs and blood of rats. There is sufficient evidence of its carcinogenicity in animals.

Exposure Limits

TLV-TWA 0.05 mg/m³ (for dusts and salts) (ACGIH), 0.2 mg/m³ (MSHA), 0.1 mg/m³ (OSHA), lowest feasible level in air (NIOSH); ceiling 0.3 mg/m³ (OSHA).

34.4 MERCURY

Symbol Hg; at. wt. 200.59; at. no. 80; valences 1, 2; CAS [7439-97-6]; a Group IIB element

Synonyms: quicksilver; hydrargyrum

Uses and Exposure Risk

Mercury is used in mercury arc and fluorescent lamps; in thermometers, barometers, and hydrometers; to extract gold and silver from ores; and as amalgams with many metals.

Physical Properties

Silvery white, heavy liquid; mobile; density 13.53 at 25°C; solidifies at −39°C; boils at 356.7°C; does not oxidize at ambient temperatures; immiscible with water; reacts with nitric acid and hot concentrated sulfuric acid.

Health Hazard

Elemental mercury and its inorganic salts, as well as organomercury compounds, are all highly toxic substances. The element has a vapor pressure of 0.0018 torr at 25°C, which is high enough to make it a severe inhalation hazard. Exposure to mercury vapors at high concentrations for a short period can cause bronchitis, pneumonitis, coughing, chest pain, respiratory distress, salivation, and diarrhea. The toxic symptoms due to its effects on the central nervous system include tremor, insomnia, depression, and irritability. A 4-hour exposure to mercury vapors at a concentration chloride, methylene chloride, carbon tetrachloride, 1,4-dichlorobenzene, dichlorodifluoromethane, ethylene dichloride, and fluorochloro lubricants. Aluminum powder and halogens in contact will burst into flame. Similar ignition can occur when aluminum is combined with many interhalogen compounds, diborane, carbon disulfide, sulfur dioxide, sulfur dichloride, oxides of nitrogen, and chromic anhydride. Aluminum reacts vigorously with acids and alkalies producing hydrogen.

33.8 ZINC

DOT Label: Flammable Solid and Danger When Wet

Symbol Zn; at. wt. 65.37; at. no. 30; CAS [7440-66-6]

Uses and Exposure Risk

Zinc is an ingredient in alloys such as brass, bronze, and German silver. It is used as a protective coating to prevent corrosion of other metals, for galvanizing sheet iron, in gold extraction, in utensils, in dry cell batteries, and as a reducing agent in organic synthesis.

Physical Properties

Bluish-white metal with luster; exposure to moist air produces a white carbonate coating; stable in dry air; melts at 420°C; boils at 908°C; malleable at 100–150°C; becomes brittle at 200°C; reacts with water.

Health Hazard

Exposure to zinc dust can cause irritation, coughing, sweating, and dyspnea. A 1-hour exposure to a concentration of 100 mg/m^3 in air may manifest the foregoing symptoms in humans. Toxic effects from inhalation of its fumes include weakness, dryness of throat, chills, aching, fever, nausea, and vomiting. Many zinc salts, such as zinc chloride [7646-85-7] and zinc oxide [1314-13-2], can produce metal fume fever when the fumes are inhaled. The oral toxicity of zinc chloride in experimental animals is moderate, the LD_{50} value in rats being 350 mg/kg (NIOSH 1986). Oral administration of this salt caused colon tumors in hamsters.

Fire and Explosion Hazard

Zinc dusts form explosive mixtures with air. In the presence of moisture the dusts may heat spontaneously and ignite in air. Reaction with water produces hydrogen. The heat of reaction may ignite the liberated hydrogen. Much vigorous reaction occurs with acids, with brisk evolution of hydrogen.

When combined with oxidizers such as chlorates, bromates, peroxides, persulfates, and chromium trioxide and subjected to impact, percussion, or heating, powdered zinc explodes. Explosion may result when the powder metal is heated with manganese chloride, hydroxylamine, ammonium nitrate (an oxidizer), potassium nitrate (an oxidizer), sulfur, or interhalogen compounds. Zinc burns in fluorine and chlorine (moist), and reacts with incandescence when mixed with carbon disulfide.

33.9 TITANIUM

DOT Label: Flammable Solid, UN 2546 (dry metal powder), UN 2878 (wet with less than 20% water)

Symbol Ti; at. wt. 47.88; at. no. 22; CAS [7440-32-6]

Uses and Exposure Risk

Titanium is added to steel and aluminum to enhance their tensile strength and acid resistance. It is alloyed with copper and iron in titanium bronze.

Physical Properties

Dark-gray metal; melts at 1677°C; boils at 3277°C; brittle when cold; strength of the metal increases by traces of oxygen or nitrogen.

Health Hazard

Inhalation of metal powder may cause coughing, irritation of the respiratory tract,

HEAVY METALS IN SOILS

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9 Lead

B.E. DAVIES

9.1 Introduction

When Pb is released into the environment it has a long residence time compared with most other pollutants. As a result, Pb and its compounds tend to accumulate in soils and sediments where, due to their low solubility and relative freedom from microbial degradation, they will remain accessible to the food chain and to human metabolism far into the future. Lead is poisonous, and there are fears that body burdens below those at which clinical symptoms of Pb toxicity appear may cause mental impairment in young children. There is no significant evidence that Pb plays any essential role in metabolism. Many investigations have been carried out on environmental Pb, including soil, over the last twenty years and we now have a detailed understanding of its soil chemistry and ecological and health significance.

Lead is a member of Group IVB of the Periodic Table of the elements. Two oxidation states (Pb(II) and Pb(IV)) are stable, but the environmental chemistry of the element is dominated by the plumbous ion, Pb^{2+}. In its elemental state, Pb is a dense (11.3 pg/cm^3) blue-grey coloured metal which melts at 327°C and boils at 1744°C. The low melting point has allowed it to be smelted, melted and worked even in primitive societies. The metal is very soft and tends to creep or flow under sustained pressure: it is therefore readily cut and shaped, and since ancient times it has been used on roofs or as pipes. Metallic Pb is relatively opaque to ionising radiation, and makes a valuable shield material in X-ray and radioisotope work. Lead readily alloys with other metals: the Pb/Sb alloy is chiefly used to make battery plates and Pb/Sn alloys are often used as solder. Lead metal, in combination with PbO_2, is used to fabricate the lead–acid accumulator battery. Other inorganic compounds are widely used, e.g., the yellow chromate is used in road markings, and many paints contain Pb oxides or Pb soaps to promote polymerisation. There is an extensive organic chemistry of Pb(IV) compounds, especially tetra-alkyl and tetra-aryl compounds.

6 Cadmium

B.J. ALLOWAY

6.1 Introduction

Cadmium belongs to group IIB of the Periodic Table, and is a relatively rare metal, being 67th in order of elemental abundance. It has no essential biological function, and is highly toxic to plants and animals. However, the concentrations of Cd normally encountered in the environment do not cause acute toxicity. The major hazard to human health from Cd is its chronic accumulation in the kidneys where it can cause dysfunction if the concentration in the kidney cortex exceeds 200 mg/kg fresh weight [1]. Food is the main route by which Cd enters the body, but tobacco smoking and occupational exposures to CdO fumes are also important sources of the metal. The FAO/WHO recommended maximum tolerable intake of Cd is 400 to 500 μg/week, which is equivalent to about 70 μg/day [1]. Average dietary intakes of Cd around the world range between 25 and 75 μg/day [2] and there is clearly a problem where the intake is near the top of the range. People who smoke can add an extra 20 to 35 μg Cd/day to their intake.

In view of the dangers of the chronic accumulation of Cd in the human body, the factors influencing its concentration in the components of the diet are of great importance. Since concentrations of the metal in uncontaminated soils are usually low, sources of contamination and the behaviour of Cd in the contaminated soils will be the main concern. With the estimated half-life for Cd in soils varying between 15 and 1100 years [3], this is obviously a long-term problem and pollution needs to the prevented or minimised wherever possible. Several countries have restricted the use of Cd, or are planning to, but nearly all have a legacy of pollution from its many sources.

Cadmium pollution of the environment has been rapidly increasing in recent decades as a result of rising consumption of Cd by industry. Environmental pollution is an inevitable consequence of metal mining, manufacture and disposal. Unlike Pb, Cu, and Hg, which have been utilised for centuries, Cd has only been widely used this century. More than half of the Cd ever used in industry was produced in the last 20 years [4]. It is obtained as a by-product of the smelting of Zn and other base metals, and no ores are used

primarily as source of Cd. World production of Cd increased from 11 000 t in 1960 to 19 000 t in 1985 [5]. Its principal uses are: (i) as protective plating on steel, (ii) in various alloys, (iii) in pigments (for plastics, enamels and glazes), (iv) as a stabiliser for plastics, (v) in Ni Cd dry-cell batteries and (v) other miscellaneous uses, including photovoltaic cells and control rods for nuclear reactors [6].

Sources of soil contamination by Cd are the mining and smelting of Cd and Zn; atmospheric pollution from metallurgical industries; the disposal of wastes containing Cd, such as the incineration of plastic containers and batteries; sewage sludge application to land; and the burning of fossil fuels [7]. Even before Cd was used commercially, contamination was occurring from a wide range of materials containing Cd as an impurity. Phosphatic fertilisers are an important example of this; their Cd contents vary, but their continual use has led to significant increases in the Cd contents of many agricultural soils. The deposition of aerosol particles from urban/industrial air pollution also affects the soils in most industrial countries, and Cd from this source can also be absorbed directly into plants through the foliage.

6.2 Geochemical occurrence

The average concentration of Cd in the Earth's crust is estimated to be in the region of 0.1 mg/kg [8,9]. Cadmium is closely associated with Zn in its geochemistry; both elements have similar ionic structures and electronegativities (a property related to the ionisation potential) and both are strongly chalcophile (see Chapter 3) although Cd has a higher affinity for S than Zn. The average Zn:Cd ratio for all rocks is around 500:1, but ranges from 27:1 to 7000:1 [10]. Cadmium is obtained as a by-product from the smelting of sulphide ore minerals in which it has substituted for some of the Zn. The most abundant sources of Cd are the ZnS minerals sphalerite and wurtzite and secondary minerals, such as $ZnCO_3$ (smithsonite) which typically contain 0.2–0.4% Cd although concentrations of up to 5% Cd can be found [6,11].

Sedimentary rocks show a greater range of Cd concentrations than other rock types, with phosphorites (sedimentary Ca phosphates) and marine black shales having the highest contents (Table 6.1). Phosphorites and black shales also contain anomalously high concentrations of several other heavy metals in addition to Cd. Both types of rock are formed from organic-rich sediments under anaerobic conditions, and the heavy metals accumulated as sulphides and organic complexes.

6.3 Origin of cadmium in soils

6.3.1 *Soil parent materials*

Page and Bingham [15] suggest that soils derived from igneous rocks would have Cd contents of 0.1–0.3 mg/kg, those on metamorphic rocks would

Cd in the dry matter have been reported for sewage sludges in western Europe and North America [52, 47]. Median values of 17–23 mg/kg Cd have been given for British sludges [53, 54]. Sommers [42] reports a median Cd content of 16 mg/kg in 150 sludges in the USA. A very low mean Cd content of 1 mg/kg has been reported for Irish sewage sludges, which is a reflection of the relatively low level of industrial development in many parts of Ireland [47]. Using an average value of 23 mg/kg for Cd in sewage sludge, Nriagu [35] estimated that the annual input of Cd into the environment from the application of sludge to land was 480 t/yr.

The metal concentrations in sewage sludges are highly variable, owing to continual changes in the composition and volume of effluents discharged into sewers. Coefficients of variation of around 70% have been found for the Cd contents of sludges sampled on different occasions within a treatment works [55, 56]. In the last decade Cd concentrations in sewage have decreased in some countries as a result of the improved pollution control, and therefore some of the values for the 1970s in Table 6.5 are higher than would be found nowadays.

The maximum acceptable Cd concentrations in sewage sludges applied to agricultural land in Europe vary from 5 mg/kg (in the Netherlands) to 20 mg/kg (in the German Federal Republic and France). The recommended maximum Cd content of sewage sludge in the Council of the European Communities Draft Directive [26] is 20 mg/kg Cd (in the dry matter) with a mandatory maximum of 40 mg/kg. In the USA, Baker [57] proposed a maximum Cd concentration of 50 mg/kg, while Chaney [58] advocated that the Cd content of sludges should not exceed 1% of the Zn content. Where Zn concentrations were high, Zn toxicity would reduce the chances of crops being consumed with high contents of Cd [58].

The recommended maximum annual Cd soil loadings from sewage sludge also vary between countries. The range for nine European countries and Canada was from 0.01 kg Cd/ha/yr (in Denmark) to 0.17 kg Cd/ha/yr (in the UK) [22]. The Council of the European Communities Draft Directive [26].

Table 6.5 Cadmium contents of sewage sludges

Cd range (mg/kg)	Source of sludge	Reference
6.8–444	16 cities (USA)	41
3–3410	150 treatment plants (USA)	42
2–1100	57 locations in Michigan (USA)	43
0.3–168	6 towns (Netherlands)	44
2–1500	42 treatment plants (UK)	45
< 1–180	200 sludges (UK)	46
< 1–90	45 treatment plants (Ireland)	47
< 2450	Bordeaux (France)	48
10–22	Helsinki (Finland)	49
2.3–171	93 treatment plants (Sweden)	50
0.3–236	7 cities (Ontario, Canada)	51

has a recommended maximum loading of 0.1 kg Cd/ha/yr and a mandatory maximum of 0.15 kg Cd/ha/yr. The current recommended maximum loading of Cd in sludge-amended soils in the UK is 5 kg/ha for all soils [59]. In the USA the guidelines for the cumulative addition of Cd in sewage sludge to soils are related to the soil CEC. The maximum cumulative loading is 5.5 kg/ha Cd for soils with a CEC of < 5 meq/100 g, 11 kg/ha Cd for 5–15 meq/100 g CEC soils and 22 kg/ha Cd for soils with CECs of > 15 meq/100 g [60]. Soils which have received abnormally large applications of sewage sludge are discussed in section 6.6.

Although an expedient form of waste disposal, and a source of N and P macronutrients, the application of sewage sludges to land does result in soils being significantly contaminated with Cd and other non-essential metals, which will inevitably lead to their increased uptake by crops.

6.3.5 *Other sources of cadmium*

The other major sources of Cd which can cause contamination of soils are the mining, ore-dressing and smelting of Cd-containing suphide ores which can contain up to 5% Cd. Dispersion of particulates from these sources can be by gravity from spoil tips, by wind, and by water through the erosion and fluvial transport of tailings from old mines and mineral dressing floors. Soils severely polluted by Pb–Zn mining have been found to contain up to 540 mg/kg Cd [61]. Cadmium-polluted soils are discussed in more detail in section 6.6.

6.3.6 *Summary of cadmium inputs into soils*

For individual western countries the relative contributions of Cd from the major anthropogenic sources have been estimated to be: phosphatic fertilisers 54–58%, atmospheric deposition 39–41%, and sewage sludge 2–5% [62, 63]. These sources give rise to an average annual increase in the Cd content of agricultural soils in Denmark of 0.6% [63]. However, much higher inputs occur at sites near metallurgical works emitting Cd or where sewage sludge is applied to land.

6.4 The chemical behaviour of cadmium in soils

6.4.1 *Speciation of cadmium in the soil solution*

It is important to be able to identify the forms of metals in the soil, especially in the soil solution, in order to more fully understand the dynamics of the metal in agricultural and natural ecosystems. The toxic effect of a metal is determined more by its form than by its concentration. The free ion Cd^{2+} is more likely to be adsorbed on the surfaces of soil solids than other species, such as neutral or anionic species.

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13 Zinc

L. KIEKENS

13.1 Essentiality

Zinc is an essential trace element for humans, animals and higher plants. Although the beneficial effect of Zn on the growth of *Aspergillus niger* was discovered by Raulin in 1869–1870, the discovery of the essentiality of Zn for higher plants in 1926 is generally attributed to Sommer and Lipman.

Zinc is also considered essential for humans and animals, i.e. a deficient intake consistently results in an impairment of a function from optimal to suboptimal, and supplementation with physiological levels of this element, but not of others, prevents or cures this impairment [1]. The recommended safe and adequate dietary intake for adults is around 15 mg/day [2]. Zinc acts as a catalytic or structural component in numerous enzymes involved in energy metabolism and in transcription and translation. Zinc deficiency symptoms in humans and animals are failure to eat, severe growth depression, skin lesions and sexual immaturity. For humans, depression of immunocompetence and change of taste acuity also occur.

Higher plants predominantly absorb Zn as a divalent cation (Zn^{2+}), which acts either as a metal component of enzymes or as a functional, structural, or regulatory cofactor of a large number of enzymes. According to Marschner [3], at least four enzymes contain bound Zn: carbonic anhydrase, alcohol dehydrogenase, Cu–Zn superoxide dismutase and RNA polymerase. Furthermore, Zn is required for the activity of various enzymes, such as dehydrogenases, aldolases, isomerases, transphosphorylases, RNA and DNA polymerases. Because of these functions, Zn is involved in carbohydrate and protein metabolism. Zinc is also required for the synthesis of tryptophan, a precursor for the synthesis of indoleacetic acid (IAA). It is clear that the most pronounced Zn deficiency symptoms, namely stunted growth and 'little leaf' rosette of trees are related to the latter physiological function of Zn.

Crops particularly sensitive to Zn deficiency are the cereals maize and sorghum, flax, hops, cotton, legumes, grapes, citrus and fruit trees (peach, apple). In general, the most permanent symptoms of Zn deficiency are interveinal chlorosis (mainly of monocotyledons), stunted growth, malformation

Czarnezki

INFLUENCE OF TAILINGS FROM THE OLD LEAD BELT OF MISSOURI ON SEDIMENTS OF THE BIG RIVER

By

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1982

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By

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ABSTRACT

Lead and zinc mining and milling have historically produced large quantities of gangue or waste rock from which most, but not all, of the minerals have been removed. For over a century (1850-1950), most of Missouri's primary lead production came from Madison and St. Francis Counties, or the so-called "Old Lead Belt" area. This area was closed in 1965 following the discovery of rich lead deposits in the Viburnum Trend, or "New Lead Belt," which today produces over 90 percent of the total U.S. lead.

During the production life of the "Old Lead Belt," two different methods of mineral benefication were employed. The first was density separation, or jigging, which produced a coarse waste material called chat. In 1915 an improved froth flotation method was developed resulting in a finer ground waste rock material (tailings) with a more effective removal of sulphide materials. Today, abandoned deposits of chat, tailings, or a mixture of the two processes remain in the "Old Lead Belt" and some contribute runoff materials to the sediments of the Big River.

Six major chat or tailings areas have been sampled and evaluated for their metal content and possible contributions to river and stream sediments and it is concluded that a contamination problem exists throughout the Leadwood, Desloge, Flat River and Bonne Terre region. Samples taken from several tailings piles contained lead concentrations ranging from 1000-3000 ppm, while some of the older tailings, or chat piles, had anamolous values reaching 7000-8000 ppm lead.

Big river sediments collected from the vicinity of the Desloge tailings pile, where a break had occurred with resultant washout into the river, had lead concentrations in the expected range of 1000-3000 ppm. However, sediments taken from Flat River Creek and in the Big River near Leadwood had lead values ranging from 10,000-60,000 ppm.

Metal contributions from the various tailings or chat heaps are discussed in relation to river sediments and elevated lead levels in fish from the Big River, and possible contamination sources and controls are presented.

INTRODUCTION

The historic "Old Lead Belt" of Missouri, approximately seventy miles (or 113 kilometers) south of St. Louis in St. Francois County, has been mined for lead since 1720 and was the nation's dominant lead producing area in 1902. It closed in the mid-1960's due to the discovery of rich lead deposits in the Viburnum Trend or "New Lead Belt."

During production in the "Old Lead Belt" two different methods of extraction were employed to remove the lead and zinc sulphide minerals from crushed rock material. The older density separation method produced a coarse waste material or "chat" and was replaced around 1915-1920 with a more efficient froth flotation technique which yielded a more finely ground waste (tailings). During these years of production, tons of tailings were created and piled into huge hills which today are scattered along the Big River and other Ozark streams.

In 1980 elevated levels of lead were found in the edible portions of black redhorse suckers(*Moxostoma duquesni*) taken from Big River. A number of studies were then carried out to determine how runoff from these tailings had affected the sediments and aquatic life of Big River downstream from these century-old tailings deposits.

Major tailings piles have been sampled and evaluated for their metal content and as possible influences on river and stream sediments in the "Old Lead Belt" region.

MATERIALS AND METHODS

Sediments and water samples were collected from the Big River and Flat River Creek. Water sampling and analysis followed the procedures suggested in *Standard Methods* (1). River sediments were taken from shallow riffle areas and put in self closing polyethylene bags for transport to the laboratory where they were dried at 100°C and fractionated in stainless steel sieves. Three grams of <40 mesh (180 μm aperture)

TABLE I

METAL VALUES IN OLD LEAD BELT TAILINGS PILES

Location	Number of Samples	Range of Metal Values in Micrograms/gram Dry Weight			
		Cd	Cu	Pb	Zn
Leadwood	24	42-200	8-46	440-6300	2000-11000
Deslodge-Big River	24	15-87	9-170	1200-3400	900-4100
Flat River (National)	112	<.3-94	36-720	950-17000	31-4200
Elvins	30	14-120	25-430	1500-16000	1800-63000
New Lead Belt Composite - Two Piles	20	19-25	27-300	420-1900	360-1800

Tailings samples from the "New Lead Belt" are shown separately at the bottom of Table I for comparison. The lower metal values reflect current state-of-the-art metallurgical processes that have increased the efficiency of removing metals from the crushed ore and rock.

CONCLUSIONS

It is concluded from this work that tailings and storm water runoff from the "Old Lead Belt" have affected the sediments of Big River and other local streams. The observed pattern of elevated lead levels suggests that the problem exists throughout the Leadwood, Desloge, Flat River, Bonne Terre region.

Water Quality Changes Below Tailings Ponds

Flow Changes

Discharges from tailings ponds which are built far upstream in the watershed, often create a permanently flowing stream where none existed before. The volume of flow is regulated by the discharge. Generally, the volume is more constant than nearby undammed streams. High flows following rainfall and low flows in dry weather are evened out. Invertebrates, fish, and amphibians living in the stream are adapted to seasonal fluctuations. Their life cycles are seriously disrupted by loss of these changes.

Temperature

The temperature of the water released from an impoundment may be quite different from streams. Impounded water warms more slowly in the spring, reaches higher temperatures in the summer, and cools more slowly in the fall. Stream organisms use temperature change as keys in their life cycle. Loss of changes in these temperature clues further disrupts the aquatic organisms life cycle. Warmer summer and fall temperatures combined with constant flow and nutrients often stimulate plant growth. Excessive plant growths produce much oxygen in the daylight, but may deplete the dissolved oxygen at night. Oxygen depletion is also a problem if there is a plant die off.

Turbidity

Turbid stream conditions result from sediment loss during dam construction and where vegetation is slow to establish. Turbidity may also be caused by tailings lost to the stream. This can occur if tailings are used on the downstream face of the dam as well as from dam or pipe failures and spills. Tailings not only add fine particulate matter to the stream, but also have the potential to add metals. Sediments stirred up during normal mill operations may appear in the stream.

Invertebrate Population Changes

There is evidence of detrimental effects of discharges on the invertebrates living in the receiving stream. Their diversity and density has dropped at times to alarmingly low levels when discharges are added to their habitat. Recovery was documented as recycling of water was begun or as retention time of water was increased.

Plant Growth

Nutrients in the waste water discharge have created excessive plant growth in the receiving stream. For some species of aquatic insects this has provided additional habitat and food supply. Their numbers have increased, but the diversity of the invertebrate community has declined. As noted before excessive plant growth creates unbalanced dissolved oxygen usage. Fungal growth can be thick enough to smother the stream substrate. Invertebrate populations and fish habitat is destroyed and dissolved oxygen is depleted at night by too much fungal growth.

Dam Siting

Small Watershed

It is an established practice to site tailings ponds in areas that will receive minimal runoff. This practice should be followed whenever possible.

Earthen Dam

Tailings dams should be avoided. To control erosion vegetation needs to be established immediately. Earthen dams lend themselves better to this than tailings. Water should not be allowed to percolate through tailings piles in order to minimize the metals transport out of the tailings. The dam should act as a barrier between the mining operation and the receiving stream.

Distant From Permanent Water

Dams for tailings ponds should not be located too close to a permanent stream. This allows room for the water in the discharge ditch to approach more normal temperature and flow conditions. This also provides a greater area for spill containment.

Before Construction

An inventory of what is present should be made. This needs to include stream size, flow, and permanence. A list of how this will change should be made. By knowing what is there and the expected changes, an evaluation of operating methods can be determined.

Closed Mine

Competent, conscientious maintenance of the area needs to be continued. Water running onto and off the area must be managed carefully. Wind and water erosion needs to be controlled. Mine water and all water running onto the area should be divided from the tailings and treated separately. All these measures should not be destroyed by crowds of people.

Prepared by: Linden Trial
Aquatic Entomologist
Missouri Department
of Conservation
June 19, 1985

Season's Greetings

MISSOURI DEPARTMENT OF CONSERVATION

MAILING ADDRESS
P.O. Box 180
Jefferson City, Missouri 65102-0180

STREET LOCATION
2901 West Truman Boulevard
Jefferson City, Missouri

Telephone: 314/751-4115
Missouri Relay Center 1-800-735-2966 (TDD)
JERRY J. PRESLEY, Director

December 29, 1992

Ms. Laura L. Splichal
Chemist
CDM Federal Programs Corp.
8215 Melrose Drive, Suite 100
Lenexa, KS 66214

Dear Ms. Splichal:

In response to your letter of December 1, 1992 regarding four inactive mining sites in southeastern Missouri, we queried our Heritage Data Base. The result of that query is reported on the enclosed sheet.

The absence of further occurrences of sensitive species and natural communities does not mean that they do not occur within the impacted ares, merely that no additional information is known at this time. This report should not be regarded as a final statement on the presence or absence of rare or endangered species or high quality natural communities; only an on-site inspection can verify the absence or existence of such species or communities.

If you have questions regarding this report don't hesitate to call.

Sincerely,

for

DAN F. DICKNEITE
CHIEF, PLANNING DIVISION

Enclosure

CDM Federal Programs Corporation
Bonne Terre, MO - St. Francois County

A deep muck fen natural community occurs 4.0 miles from the project site. This is an Endangered natural community.

> Rigid sedge (Carex tetanica) occurs in this fen wetland. This species is listed Status Undetermined. The record is from 1983.

Another fen natural community occurs at Coonville Creek Natural Area in St. Francois State Park (DNR) 3.8 miles from the project site. This is a Rare natural community.

> Tussock sedge (Carex stricta), state listed Rare; a sedge (Carex sterilis), state listed Endangered and queen of the prairie (Filipendula ruba), state listed Endangered, occur in this fen wetland. The records are from 1992, 1992 and 1984 respectively.

Springs and spring branches (Ozark) natural communties occur 2.0 miles from the project site.

Another fen natural community occurs 3.3 miles from the project site. This is a Rare natural community.

> Rigid sedge (Carex tetanica) occurs in this fen wetland. This species is state listed Status Undetermined. The record is from 1983.

Queen of the prairie (Filipendula rubra) occurs 4.0 miles from the project site. This species is state listed Endangered. The record is from 1983.

CDM Federal Programs Corporation

Leadwood River Access (MDC) is located 3.6 miles from project site.

St. Joe State Park (DNR) is located 0.75 miles from the project site.

St. Francois State Park (DNR) is located 9.5 miles from project site downstream along Big River.

APPENDIX D

Previous Studies Analytical Data Summary

/

REFERENCE 14

LEAD CONCENTRATIONS IN FISH AND MOLLUSCS TAKEN FROM MISSOURI'S OLD LEAD BELT

DRAFT

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Presented at the Annual Meeting of the Missouri Water Pollution Control Association, February 23, 1986, Springfield, MO.

LEAD CONCENTRATIONS IN FISH AND MOLLUSCS TAKEN FROM MISSOURI'S OLD LEAD BELT

Abstract

Since 1981 the University of Missouri at Rolla, with the cooperation of the Missouri Conservation Department and St. Joe Minerals Corporation, has been assessing the enviromental impact of past mining operations in Missouri's Old Lead Belt. Potential problems exist there due to erosion of abandoned tailings piles created by more than a century of lead mining. Filets of suckers and some species of sunfish collected from various sites along the Big River and its tributaries have been found to contain concentrations of lead in excess of 0.3 ug/g, the suggested limit for lead in food promulgated by the World Health Organization. Most specimens, however, have lead concentrations below the less stringent level of 1.0 ug/g recognized in the United Kingdom as permissible levels of lead in commercial food.

Introduction

Underground mining in the southeast region of the state of Missouri, known as the Old Lead Belt, began in the 1860's and ended in 1972. During this time more than 8 million tons of lead were produced (1), leaving behind more than 227 million tons of crushed rock in the form of chat, tailings, and fine mill slime. These make up the piles of industrial waste and associated slime ponds located near the communities of Bonneterre, Desloge, Leadwood, and Flat River. More than 16,000 people live in these communities and many local inhabitants play, swim, fish, and sunbathe in and around streams and ponds extensively sedimented by eroding tailings materials. These piles have become a large part of recreational life even though they contain many residual heavy metals.

Chat is a coarse waste rock resulting from the early milling and jigging techniques of mining. Although it contains a large amount of residual metal (2) it is fairly resistant to erosion. When froth flotation procedures of separation were employed in 1915, a much finer ground waste material was produced, which accumulated in tailings piles and slime ponds. Although these contain fewer residual metals than chat, they are much smaller and more susceptable to erosion.

Missouri's New Lead Belt, or Viburnum Trend, has been in operation since 1968. Six new mine - mill complexes and two new smelters began producing more than 575,000 tons of lead in 1972 making Missouri the world's leader in lead production (3).

The New Lead Belt, since the beginning of operation, has been made to operate under stringent laws for waste disposal, set by several regulatory agencies at state and federal levels. The Old Lead Belt on the other hand operated during a time when only a few laws concerned with enviromental protection or waste disposal existed.

Enviromentalists for many years have expressed concern over the change from the typical rock-bottom ozark stream, to a sandy bottom stream, caused by erosion of tailings materials into local rivers. Because of the alkaline pH and natural hardness of the water, solubility of lead, zinc, cadmium, and copper is limited. Almost all river water samples taken in the past were well within the USEPA standards for drinking water (50 ug/l). Lead concentrations in tailings material usually fall between 1,000 to 3000 ug/g. Samples of chat commonly contain concentrations of lead as high as 9,000 ug/g. River sediment samples have been shown to contain lead concentrations around 1,000 - 2,000 ug/g, reflecting the lead concentration of eroded tailings material. Some river sediment samples occasionally displayed 10,000 - 14,000 ug/g lead. One anomalous sample contained more than 173,000 ug/g lead (4). Such areas of high lead concentration may be caused by naturally occuring galena deposits. River flow also horizontally displaces and then concentrates heavy metals in irregular patterns.

The determination of lead in various fish tissues, has been the subject of the last four years of research in determining the magnitude of possible health problems faced by residents living in this area, who consume fish taken from these streams. Preliminary data presented in 1980 by the Missouri Department of Conservation (5) first called attention to elevated lead concentrations in fish taken from the Big River downstream from the Desloge tailings pile. Warnings appeared soon thereafter in the news media against eating suckers taken from the Big River for 50 miles downstream of Desloge. Subsequent studies done in 1981 and 1982 showed that no emergency existed, but that the situation should be monitored regularly.

Species of fish most likely to contain elevated concentrations of lead include the Black Redhorse sucker (Moxostoma duquesnei), and Northern Hogsucker (Hypentelium nigricans). These two species of suckers are known for their bottom feeding activities through which they ingest a great amount of sediment as they look for insect larvae and crustaceans. These suckers are also known to migrate extensively during spawning season and while feeding. The Longear Sunfish (Lepomis megalotis) is also omnivorous and ubiquitous and often feeds in close proximity to suckers, turtles, etc. eating insects, crayfish, and considerable sediment which these other organisms stir up. These sunfish are attractive subjects, since they do not usually migrate far from the site where they are spawned. A variety of other fish species has been sampled, including catfish, carp, largemouth bass, smallmouth bass, other sunfish, and freshwater drum. Species of fish known to feed on or near the bottom may be expected to accumulate heavy metals from ingestion of contaminated sediments. Smallmouth bass, largemouth bass, bluegill sunfish, and other species which commonly feed higher in the water column are less likely to accumulate heavy metals.

The use of clams as indicator organisms for lead contamination in the Big River was first proposed by Schmitt and Finger in 1982 (6). This is a good idea since clams are benthic filter feeding organisms that ingest sediment as they filter nutrients from the water, and tend to accumulate heavy metals in their soft body tissues and their shells. In 1984, Corbicula leana, also known as the "Asiatic Clam", was chosen for study because of its distribution throughout the Meramec River Basin and relative abundance in several collection sites. Clams could not be collected at all sampling sites due to the alteration of the benthic environment by the fine sediments brought in by erosion of old tailings piles. Clams live best in a rocky environment where they can bury themselves in the stones, extend their siphons, and rely on currents to bring nutrients to them. If large amounts of sediments are present on the bottom, they cannot feed properly, thus they cannot be found in these areas.

The World Health Organization (WHO) has suggested limits for the maximum amount of lead in the diet. These limits are 0.3 ug/g or a total of 450 ug/day (7). Limited studies on toxicity of dietary lead in humans have shown that doses of 600 ug/day resulted in barely detectable levels of lead in the urine and no apparent increase in blood lead (8). Doses as high as 2,000 ug/day, however, cause elevated blood lead levels which invariably lead to symptoms of lead toxemia. Providing for individual variability and certain safety margins, the United Kingdom has set its own limit of 1.0 ug/g lead in food for sale (9). The United States and most other countries have no legislated limits for dietary lead.

There were several important reasons for research to continue in this area in 1985. Continued surveillance of several sites along the Big River seems prudent, since lead concentrations in suckers often approach recommended limits. Public health implications for the many residents of local communities who consume large amounts of fish taken from area rivers are of great general concern. Efforts were also made to assess the impact of the most recent episode of serious erosion of the Desloge tailings pile which occurred in spring, 1985. The USEPA is currently considering arguments that lead mine tailings may be considered "hazardous wastes", making the Desloge tailings pile a possible target of the "superfund" for correction. A very sound data base is required for scientists and engineers to make such decisions.

Materials and Methods

Fish were taken by electrofishing or by hook and line during the months of July and August. They were then measured, scaled, and fileted on site using stainless steel filet knives. Appropriate tissues were placed in self-closing polyethylene bags and held on ice during transport to the laboratory. There they were subjected to standard wet ashing procedures. Aliqudts of various tissues weighing between 1 - 5 g were mixed with 15 ml of redistilled nitric acid and 5 ml of 70% perchloric acid in 100 ml Kjeldahl flasks. They were then placed on medium heat until the white fumes of perchloric acid appeared, then heated an additional eight minutes on low heat setting. Extreme care was taken to keep the tissue aliquots below seven grams to prevent explosions. Digested samples, duplicates, and control blanks were diluted to 50 ml with 1% HNO_3, and placed in acid cleaned polypropylene bottles for analysis. Analysis for lead was done by the Enviromental Trace Substances Research Center in Columbia Missouri using graphite furnace atomic absorption spectrometry with standard additions to correct for matrix effects.

Fresh water clams (Corbicula leana) were collected during the months of August and early September from riffle zones and shallow pools. They were collected by hand and placed in large, clean plastic buckets filled with a few inches of river water for transport to the laboratory. Once in the laboratory they were held in aquaria with daily changes of spring water (Martin Spring - Rolla) and allowed to purge their gastro-intestinal contents for varying lengths of time. The clams were then scrubbed with a clean nylon test tube brush, measured, then dissected with steel surgical scalpels. Soft tissue samples were pooled and frozen in clean plastic tubes. After four or five days aliquots were taken for wet ashing procedures described above. Aliquots of clam shells were digested with 10 ml of redistilled nitric acid. They were heated on medium heat until the volume was reduced to approximately 5 ml, then diluted to 50 ml with 1% HNO_3 and subjected to elemental lead analysis as previously described.

Sediment samples were taken at each site using clean plastic drinking cups. Where possible, separate samples were taken from pool and riffle zones, placed in clean self-closing polyethylene bags and returned to the laboratory. Samples were dried in a dust free enviroment, sieved, and the <20 mesh fractions were digested in redistilled HNO_3. Digested sediment samples, duplicates, and laboratory standards were subjected to ICAP (Induction Coupled Argon-Plasma) analysis.

Collection sites in the Old Lead Belt are shown in Figure 1, and listed below together with the dates samples were collected.

Old Lead Belt

1. Big River at Mo.-Ill. railroad trestle (control) (7/16)
2. Big River at Leadwood Public Access (7/16)
3. Big River at Washington State Park (7/29)
4. Eaton Creek at Highway 8 (7/29)
5. Big River at Eaton Creek (7/29)
6. Big River at St. Francois Cemetery (7/30)
7. Big River at Bonneterre Hwy 67 North (7/30) Down Stream
8. Flat River Creek at National tailings pile (7/30)
9. Big River at House Springs Public Access (7/31)
10. Big River at St. Francois State Park (7/31) Down Stream
11. Big River at Highway K (Johnsons Campground (7/31) UP Stream

New Lead Belt

12. Strother Creek below junction with Neals (8/13)
13. Strother Creek at property line (8/13)
14. Strother meanders, middle (8/13)
15. AMAX upper tailings pond (8/13)
16. AMAX lower tailings pond (8/13)

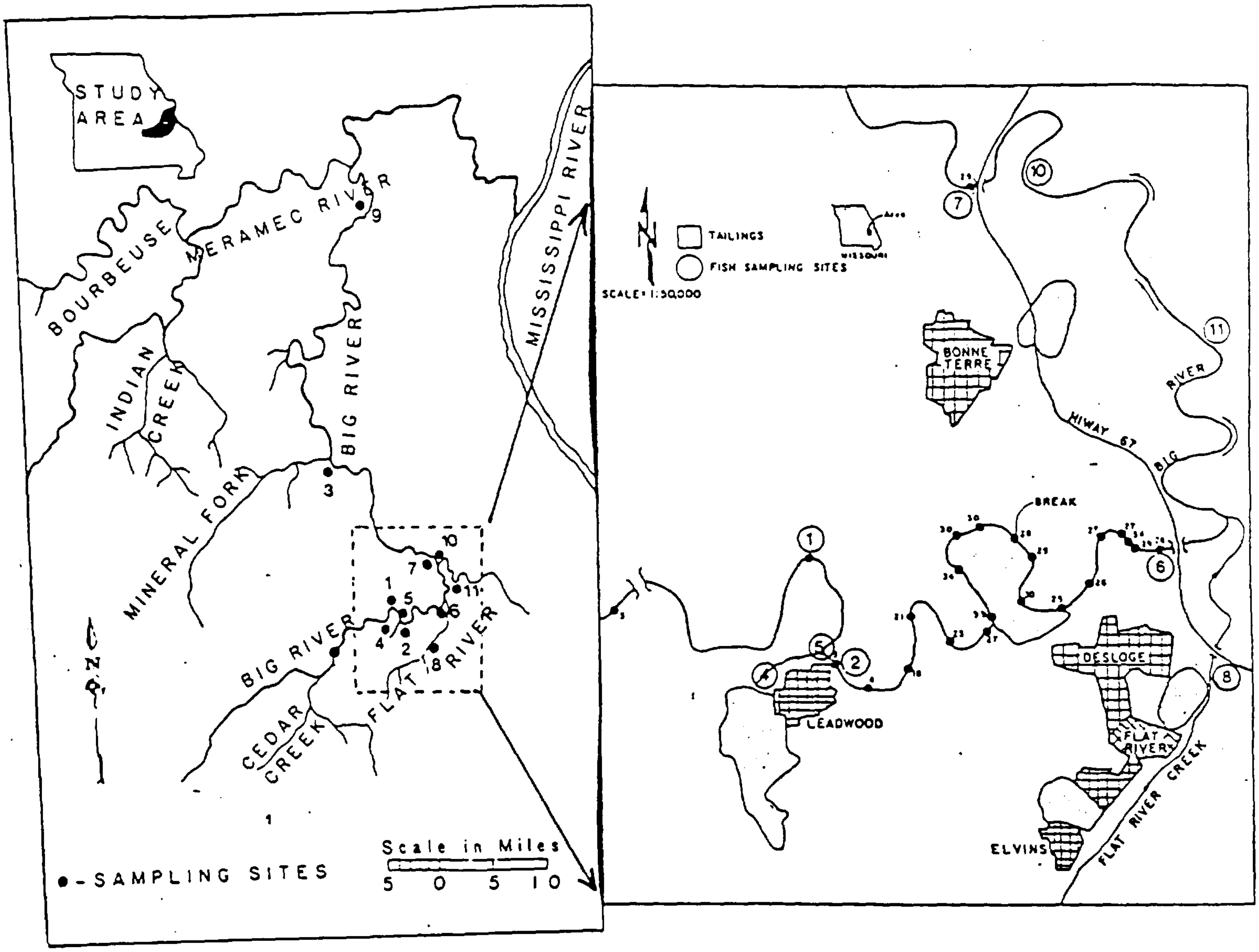
Clams were collected at the Big River at Washington State Park, Big River at Eaton Creek, and the Big River at House Springs Public Access.

Results & Discussion

Lead in Fish - Old Lead Belt

Table 1 shows a summary of the concentrations of lead in fish taken from the Old Lead Belt during 1985. The concentrations of lead in sunfish are all below the WHO reccommended limit of 0.3 ug/g, except for site number 8, Flat River Creek at the National Tailings Pile, which showed a mean value of 0.392 ug/g lead. Sunfish collected at the control site number 1, approximately 2 miles upstream of Leadwood Public Access had mean lead concentrations of <0.048 ug/g (below detection limits). However, one single sunfish filet specimen from this control site was found to have 0.807 ug/g, but because it was such an anomalous value, it was omitted from the calculated mean. Similarly, a sunfish specimen from site number 3, Washington State Park was found to have an observed lead concentration of 2.67 ug/g. This anomalous value was also omitted from calculated means. There

Fig. 1: LOCATION OF COLLECTION SITES



LEGEND:

1. Big River at Mo.-Ill. railroad trestle
2. Big River at Leadwood Public Access
3. Big River at Washington State Park
4. Eaton Creek at Highway 8
5. Big River at Eaton Creek
6. Big River at St. Francois Cemetery
7. Big River at Bonneterre Hwy. 67 North
8. Flat River Creek at National tailings pile
9. Big River at House Springs Public Access
10. Big River at St. Francois State Park
11. Big River at Highway K

Table 1:

SUMMARY - LEAD IN FISH OLD LEAD BELT SUMMER 1985

SITE NUMBER		SUNFISH	NORTHERN HOGSUCKERS	BLACK REDHORSE	CATFISH	CARP
1		<.048	.103	.069	--	--
	S	20	4	6	--	--
	N	10	2	3	--	--
*4		.239	--	--	.812	--
	S	6	--	--	1	--
	N	6	--	--	1	--
5		.156	--	--	--	--
	S	6	--	--	--	--
	N	6	--	--	--	--
2		.119	.379	.854	--	.087
	S	20	6	2	--	8
	N	10	3	1	--	1
6		.220	.220	--	--	1.10
	S	25	2	--	--	5
	N	13	1	--	--	1
*8		.392	.728	--	.254	--
	S	6	5	--	2	--
	N	6	5	--	2	--
D 11		.226	.676	.573	--	--
	S	7	5	5	--	--
	N	7	5	3	--	--
D 10		.173	.588	.455	--	--
	S	7	3	1	--	--
	N	7	3	1	--	--
D 7		.247	.793	.446	.330	--
	S	10	1	5	2	--
	N	10	1	5	2	--
3		.152	.377	--	.114	--
	S	14	11	--	6	--
	N	7	5	--	2	--
						DRUM
9		.149	.206	.185	--	.345
	S	17	1	11	--	4
	N	17	1	11	--	4

S = NUMBER OF SAMPLES ANALYZED
N = NUMBER OF INDIVIDUALS
*TRIBUTARIES OF THE BIG RIVER.

[redacted] [redacted]

Historical Trends of Sunfish Summer 1985

Table 3:

COLLECTION SITE		1981	1982	1983	1984	1985
Big River at Mo.-Ill. Railroad Trestle	MEAN	.090	.052	.071	<0.048	<0.048
	STD. DEV.	.050	.010	.006	.007	.006
Eaton Creek	MEAN	--	--	--	.158	.239
	STD. DEV.	--	--	--	.100	.101
Big River at Eaton Creek	MEAN	--	.107	.145	.156	.156
	STD. DEV.	--	.040	.096	.090	.031
Big River at Leadwood	MEAN	.550	.200	.086	.150	.119
	STD. DEV.	.350	.150	.020	.080	.064
Big River at St. Francois Cemetery	MEAN	.300	.324	.184	.215	.220
	STD. DEV.	.190	.440	.100	.130	.075
Flat River Creek at National Tailings Pile	MEAN	.910	.300	.310	.439	.392
	STD. DEV.	.500	--	.170	.120	.210
Big River at Hwy. K Johnson's Campground	MEAN	--	--	--	--	.226
	STD. DEV.	--	--	--	--	.097
Big River at St. Francois State Park	MEAN	--	--	--	--	.173
	STD. DEV.	--	--	--	--	.031
Big River at Bonneterre Hwy. 67 North	MEAN	.480	.240	--	.209	.247
	STD. DEV.	.350	.170	--	.110	.140
Big River at Washington State Park	MEAN	--	--	--	.565	.152
	STD. DEV.	--	--	--	.540	.082
Big River at House Springs	MEAN	--	--	--	.089	.149
	STD. DEV.	--	--	--	.065	.035
Monsanto Lake	MEAN	--	--	--	<0.047	--
	STD. DEV.	--	--	--	.004	--

Table 4:

HISTORICAL TRENDS OF COMBINED SUCKERS SUMMER 1985

COLLECTION SITE		1981	1982	1983	1984	1985
Big River at Mo. -Ill. Railroad Trestle	MEAN	.074	.058	--	--	.083
	STD. DEV.	.063	.032	--	--	.039
Eaton Creek	MEAN	--	--	--	--	--
	STD. DEV.	--	--	--	--	--
Big River at Eaton Creek	MEAN	.375	--	--	--	--
	STD. DEV.	.064	--	--	--	--
Big River at Leadwood	MEAN	.754	.358	--	.300	.498
	STD. DEV.	.531	.243	--	.089	.320
Big River at St. Francis Cemetery	MEAN	.805	.470	--	.581	.220
	STD. DEV.	.462	.08	--	.392	.075
Flat River Creek at National Tailings Pile	MEAN	1.07	.31	.751	.695	.728
	STD. DEV.	.850	.20	.40	.281	.270
Big River at Hwy. K Johnson's Campground	MEAN	--	--	--	--	.624
	STD. DEV.	--	--	--	--	.240
Big River at St. Francis State Park	MEAN	--	--	--	--	.555
	STD. DEV.	--	--	--	--	.070
Big River at Bonneterre Hwy. 67 North	MEAN	.540	.49	--	.379	.504
	STD. DEV.	.309	--	--	.199	.159
Big River at Washington State Park	MEAN	--	--	--	.363	.377
	STD. DEV.	--	--	--	.090	.175
Big River at House Springs	MEAN	--	--	--	--	.186
	STD. DEV.	--	--	--	--	.061

ble 10:

Sediment Analysis Summer 1985

STATION		Cd	Co	Cr	Cu	Ni	Pb	Ca	Fe	Mg	Mn	Zn
1	Pool	<0.2	3.10	10	1.60	3	14	544	6280	306	148	23
	Riffle	<0.2	4.30	11.50	3.80	5.45	135	1390	7825	647	354	31
4	Pool	125	27	6.50	72	12	770	162000	21700	78900	3190	6465
	Riffle											
5	Pool											
	Riffle	165	13	7	52	7.95	3585	62600	12700	31200	1475	8900
2	Pool	217	8.30	9.20	7.70	5.95	1220	15400	9870	7500	486	8795
	Riffle	33	8.30	7.30	3.60	7.70	1483	11700	6520	5720	405	1500
6	Pool	46	10.70	<1.00	7.70	6.95	1200	157700	24200	74900	3260	2200
	Riffle											
8	Pool	6.50	55	<1.00	245	39.30	1060	180000	35250	81450	4000	378
	Riffle	6	35	<1.00	160	25	1200	180000	37300	80800	4270	289
11	Pool	21	14	<1.00	33	8.60	1000	144000	24200	67500	3220	1100
	Riffle	30	17	<1.00	28	9.90	1550	161000	26800	75700	3530	1580
10	Pool	5.70	10	2.40	7.50	7.90	625	93500	18750	44350	2275	362
	Riffle	4	13	8	7	9.60	840	118000	22400	56000	2740	316
7	Pool	8.60	16	2	23	9.20	710	110000	20800	51900	2660	488
	Riffle	4	10	3	5	6.60	550	111000	20500	52500	2590	307
3	Pool	2.20	8	10	5	5.60	430	27600	10500	13700	864	162
	Riffle	2	7	8	6	4.70	470	34400	11000	17100	1020	140
9	Pool	.40	1.65	3.75	1.50	2	66	717	2500	242	105	33
	Riffle	<.20	1	3.60	.90	1	46	291	2010	114	80	26
NEW LEAD BELT												
12	Pool	.30	13	7.20	5.30	20	134	6070	4700	1480	356	85
	Riffle											
13	Pool	<.20	67	6	6.50	96	110	15000	5930	8490	1060	230
	Riffle	<.20	41	6.90	5.50	51	73	10800	6990	5850	576	153
14	Pool	2	160	10	35	170	508	15300	7830	8660	569	875
	Riffle	.95	80	8	14	67	507	23500	5900	13500	470	375

Fig. 2:

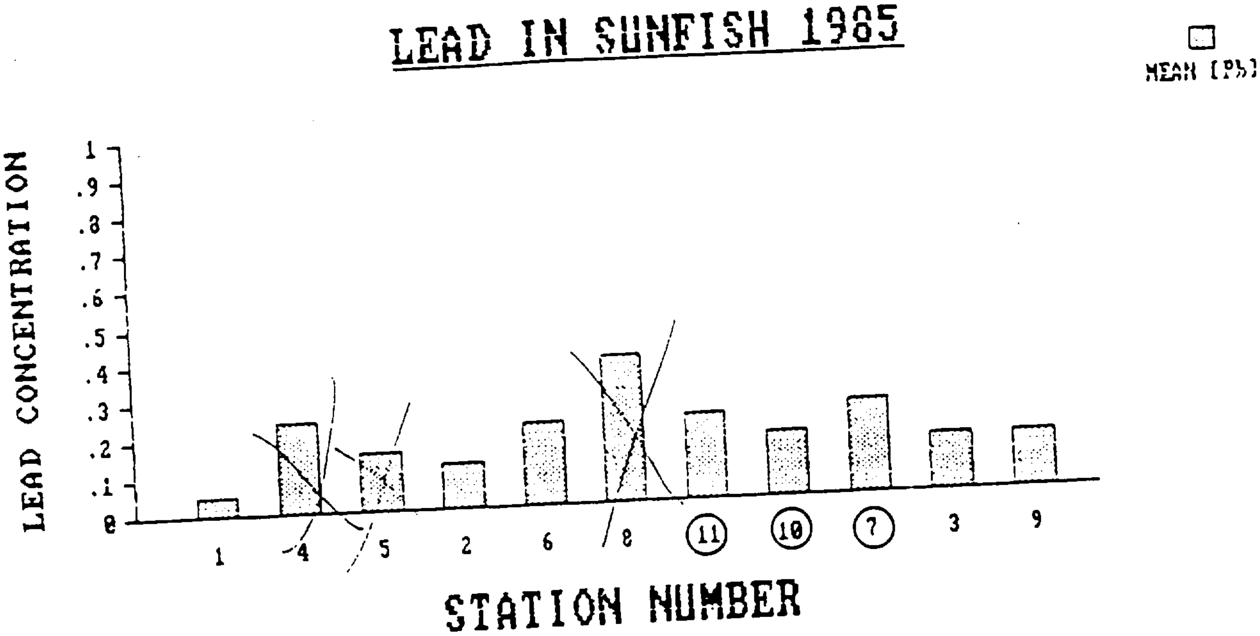
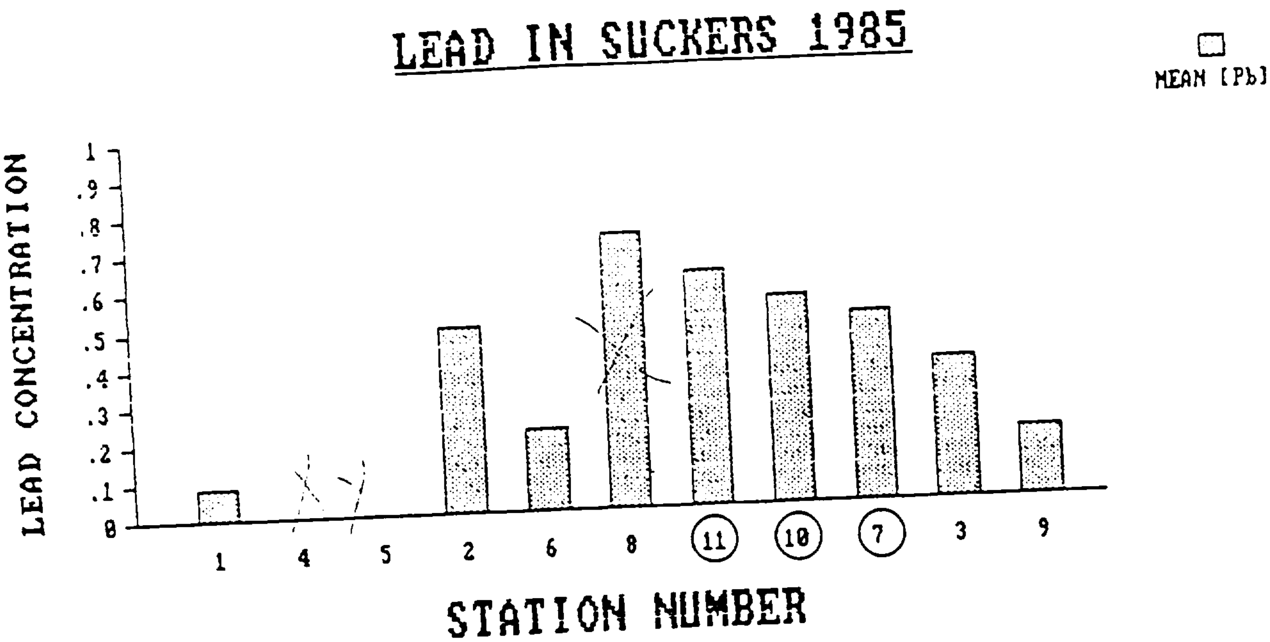

LEAD IN SUNFISH 1985
MEAN [Pb]
LEAD CONCENTRATION
1
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
1
4
5
2
6
8
11
10
7
3
9
STATION NUMBER

Fig. 3:



LEAD IN SUCKERS 1985
MEAN [Pb]
LEAD CONCENTRATION
1
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
1
4
5
2
6
8
11
10
7
3
9
STATION NUMBER

A STUDY ON THE POSSIBLE USE OF CHAT AND TAILINGS FROM THE OLD LEAD BELT OF MISSOURI FOR AGRICULTURAL LIMESTONE

A Research Report
Submitted to the
Missouri Department of
Natural Resources
P.O. Box 1368
Jefferson City, Missouri 65102

by
Bobby G. Wixson
Nord L. Gale
and
Brian E. Davies *

The University of Missouri - Rolla
Rolla, Missouri 65401

* Visiting Professor, University
of Wales - Aberystwyth

December 1983

tailings piles exist in the "Old Lead Belt" area of Missouri. These are 1) chat; 2) tailings; 3) a mixture of chat and tailings representing historical changes in ore separation and mineral collection technology.

These rather dominant waste hills or deposits of chat or tailings, unless specially treated, will remain sterile of vegetation because of unfavorable physical properties (e.g., surface instability or moisture retention characteristics), lack of essential plant nutrients, and residual concentrations of heavy metals. The tailings or chat heaps may be unsightly and environmentally damaging if the rock waste material is blown or washed from the hills into neighboring fields or waterways (2). The most common ameliorative practice to date has been by landscaping and revegetation. However, the chat or tailings heaps also offer the possibility of being used as an economically valuable material such as in building foundations, highway construction and use of the calcareous material as agricultural limestone. However, questions were raised concerning residual heavy metal content which might restrict the use of tailings or chat for use as agricultural limestone purposes.

According to Davies and Roberts (3) and other studies (4), similar reuse of limestone tailings in north Wales (Great Britain) was believed to have contributed to the formation of a major contamination area (171 km^2 contaminated by Pb) resulting in significant problems of heavy metal uptake by vegetables. Also, the residual organic content following froth flotation had limited reuse in Derbyshire, England (5).

The Missouri Department of Natural Resources (DNR) has been constan asked by the public and the mining industries if the tailings, or chat, materials in the Old Lead Belt area might be used as agricultural limes contain high levels of dissolved calcium, magnesium, zinc and lead which have an impact on the sediments and biota of Flat River Creek.

The Elvins tailings pile was studied in 1976 by Kramer (16) and the growth of algae in the zinc rich wastes and seepage water has been reported by Whitton, et al (17). Presently a small asphalt paving plant operates on the southern perimeter of the tailings pile with the tailings being used as a finer sized aggregate source.

Figure 9 illustrates the location of 91 sampling sites on the Elvins tailing pile. Table 11 gives the metal concentrations of Pb, Cd and Zn found at the sampling locations.

E. Bonne Terre

The Bonne Terre tailing deposits consist of two different areas and configurations. A large chat and tailings dome is situated on the east side of Bonne Terre, Missouri and covers an area of approximately 50 acres of land. The second area is located about 1/2 mile to the west of the chat hill just across Missouri Highway 67 and is a mostly dried-up tailings pond covering about 272 acres.

Figure 10 gives the location of sampling sites on the Bonne Terre tailings pile which is shaped like a small hill overlooking a golf course. Table 12 lists the metal concentrations found for Pb, Cd and Zinc at the tailings pile.

Figure 11 shows the location of sampling sites on the flat tailings deposits of the Bonne Terre east deposit which still has water confined at one end. Table 13 gives the metal concentrations found for Pb, Cd and Zn at the recorded sampling locations.

F. Statistical Analysis of Different Tailings Piles

Heavy metal data from the characterization of the different tailings and chat piles studied were statistically evaluated for

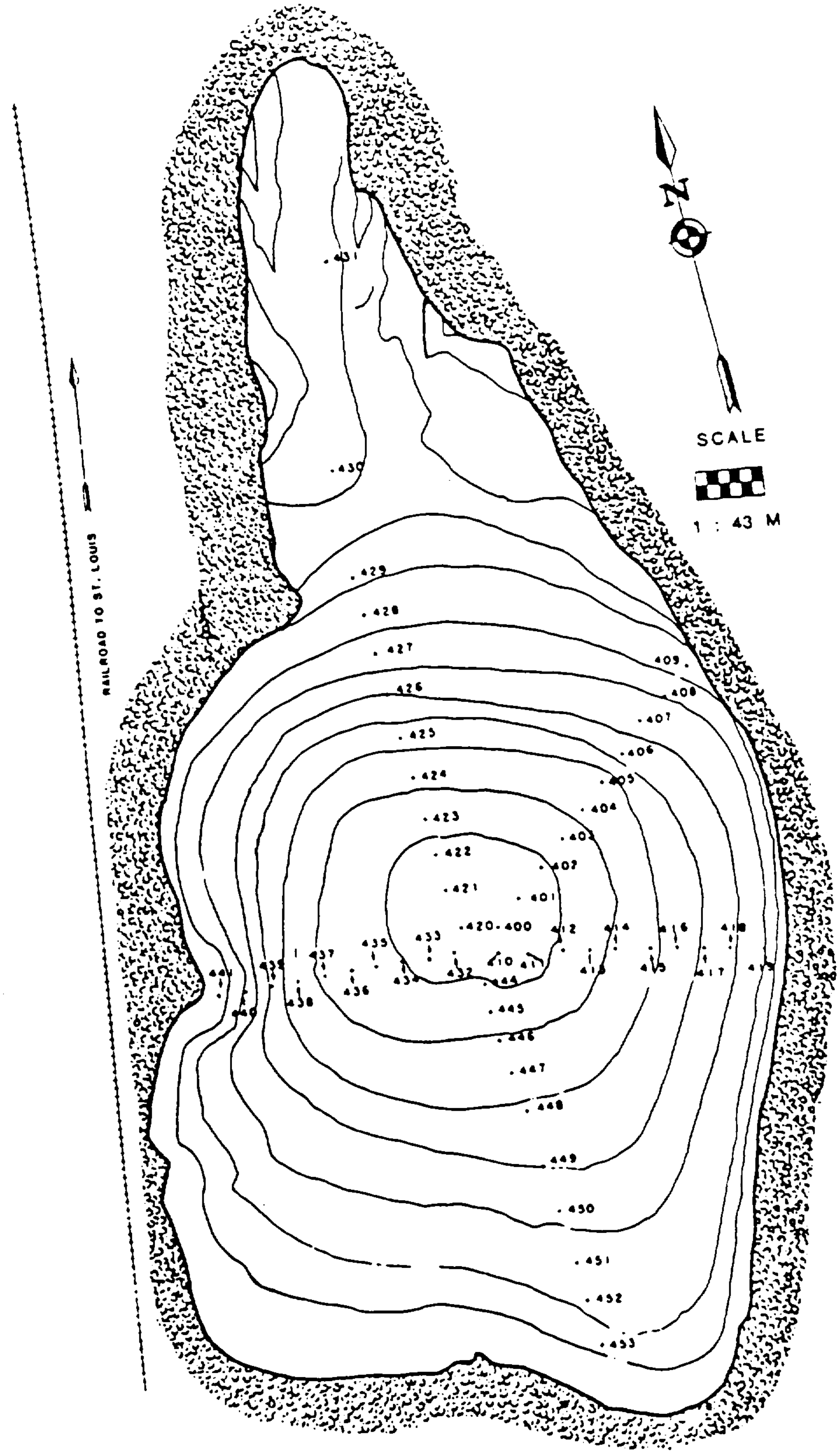


FIGURE 10. LOCATION OF SAMPLING SITES ON BONNE TERRE TAILINGS PILE.

TABLE - 12
BONNE TERRE TAILINGS PILE

Sample No.	Metal Conc; ug/g		
	Pb	Cd	Zn
BT400	5330	9.7	469
BT401	5020	5.4	273
BT402	1300	10.2	309
BT403	2020	9.9	430
BT404	2280	11.7	451
BT405	3540	11.9	689
BT406	3070	12.1	718
BT407	1890	17.6	650
BT408	1540	12.3	587
BT409	3230	14.9	501
BT410	3590	13.9	51.3
BT411	4120	13.4	671
BT412	4450	17.7	757
BT413	3140	14.4	722
BT414	4350	12.0	309
BT415	2540	16.1	757
BT416	3040	16.4	648
BT417	1630	9.6	486
BT418	1840	13.7	597
BT419	1760	10.0	641
BT420	1480	3.0	150
BT421	3080	5.5	194
BT422	2050	13.3	434
BT423	1940	13.0	479
BT424	2190	13.5	458
BT425	2380	15.1	573
BT426	2390	17.2	622
BT427	1580	15.1	553
BT428	1860	14.2	686
BT429	1340	13.9	661
BT430	4720	29.5	786
BT431	2650	7.0	150
BT432	3200	15.2	705
BT433	3200	15.8	650
BT434	7010	8.2	426
BT435	6670	15.3	477
BT436	5820	10.9	361
BT437	5210	18.1	559
BT438	4290	11.5	573
BT439	6730	13.6	755
BT440	6840	12.8	618
BT441	5800	16.0	180

TABLE - 12

BONNE TERRE TAILINGS PILE

Sample No.	Metal Conc; ug/g		
	Pb	Cd	Zn
BT444	3280	15.1	511
BT445	4530	13.6	444
BT446	4220	17.4	697
BT447	5030	19.2	746
BT448	5980	22.5	967
BT449	5190	28.8	623
BT450	3390	22.4	922
BT451	3540	22.0	878
BT452	2791	15.7	563
BT453	6230	10.4	539

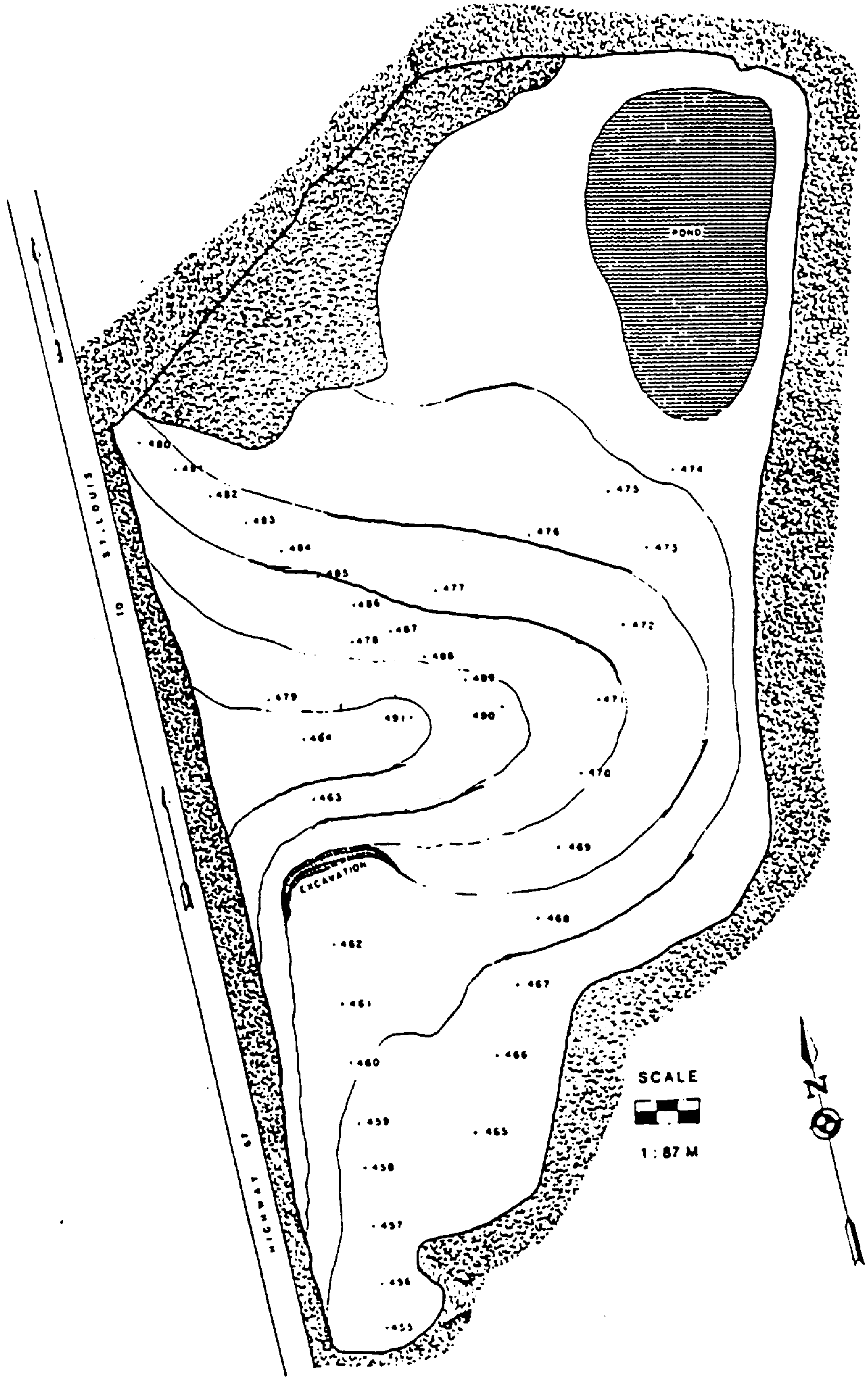


FIGURE 11. LOCATION OF SAMPLING SITES ON BONNE TERRE TAILINGS FLAT.

TABLE 13
BONNE TERRE TAILINGS FLAT

Sample No.	Metal Conc; ug/g		
	Pb	Cd	Zn
BT455	1232	5.9	173
BT456	3020	10.2	361
BT457	6650	10.5	312
BT458	1810	5.9	385
BT459	1600	9.0	354
BT460	1920	12.3	491
BT461	1170	9.3	312
BT462	1610	10.0	234
BT463	989	8.4	185
BT464	1560	7.3	205
BT465	1550	11.2	244
BT466	2310	12.0	380
BT467	1540	10.8	366
BT468	3450	10.4	243
BT469	1620	9.5	255
BT470	1860	6.0	157
BT471	1520	4.5	87.2
BT472	2710	6.3	222
BT473	1170	3.6	99.5
BT474	660	7.9	151
BT475	1440	4.7	156
BT476	2610	4.9	330
BT477	1320	6.0	165
BT478	1900	13.2	337
BT479	1760	9.8	273
BT480	1290	13.8	524
BT481	1480	15.1	543
BT482	1780	13.3	321
BT483	1820	5.6	618
BT484	1400	6.7	171
BT485	2840	10.0	1470
BT486	7610	20.9	698
BT487	1590	6.7	152
BT488	1020	6.4	115
BT489	1950	8.1	321
BT490	1120	5.2	170

MISSOURI DEPARTMENT OF NATURAL RESOURCES
DIVISION OF ENVIRONMENTAL QUALITY
P.O. BOX 176 JEFFERSON CITY, MISSOURI 65102 314/751-5331

REPORT OF SAMPLE ANALYSIS FOR PUBLIC WATER SYSTEM

MAIL TO: PWS OFFICE COPY
THE HONORABLE JACK LAWSON
DANNY DEGONIA

BONNE TERRE
PSW ID: 4010087
COUNTY: ST. FRANCOIS
REPORT DATE: 12/28/89
SAMPLE TYPE: SPECIAL

COLLECTION TECHNIQUE: GRAB
LOCATION: NEW WELL #3
DATE COLLECTED: 11/09/89
TIME: 1230
COLLECTED BY: DANIEL DEGONIA

SOURCE: GROUND /RAW
LABORATORY: DOH
LAB LOG: 903010
METHOD: STD-INORG
ANALYSIS DATE: 12/05/89

	PARAMETER		RESULTS mg/l	REMARKS
001	PH		7.5	
002	RESIDUE-FILTER		467.	
003	FIXED		345.	
004	SULFATE		68.	
005	ALKALINITY-TOTAL		345.	
006	PHENOLPHTALEIN		0.	
007	BICARBONATE		420.4	
008	CARBONATE		0.	
009	CHLORIDE		3.0	
010	CALCIUM		70.1	
011	MAGNESIUM		50.9	
012	HARDNESS-TOTAL		385.	
013	CARBONATE		345.	
014	NON-CARBONATE		40.	
015	ARSENIC	<	0.005	
016	SELENIUM	<	0.0050	
017	LEAD	<	0.005	
018	CADMIUM	<	0.0050	
019	BARIUM	<	0.20	
020	CHROMIUM	<	0.025	
021	SILVER	<	0.01	
022	IRON		0.48	SECLIM EXC
023	MANGANESE		0.03	
024	ZINC	<	0.10	
025	COPPER	<	0.01	
026	SODIUM		4.8	
027	POTASSIUM		1.4	
028	MERCURY	<	0.0005	
029	FLUORIDE	<	0.10	
030	NITRATE-N	<	0.05	

MISSOURI DEPARTMENT OF NATURAL RESOURCES
DIVISION OF ENVIRONMENTAL QUALITY
P.O. BOX 176 JEFFERSON CITY, MISSOURI 65102 314/751-5331

REPORT OF SAMPLE ANALYSIS FOR PUBLIC WATER SYSTEM

MAIL TO: PWS OFFICE COPY

DANNY DEGONIA
LOUISE BOUCHARD

BONNE TERRE
PSW ID: 4010087
COUNTY: ST. FRANCOIS
REPORT DATE: 06/13/91
SAMPLE TYPE: ROUTINE

COLLECTION TECHNIQUE: GRAB
LOCATION: #1 WELL CHLORINE ROOM
DATE COLLECTED: 05/13/91
TIME: 0910
COLLECTED BY: DANIEL DEBONIA

SOURCE: GROUND /FINISHED
LABORATORY: DOH
LAB LOG: 910171
METHOD: STD-INORG
ANALYSIS DATE: 05/29/91

	PARAMETER		RESULTS mg/l	REMARKS
001	PH		7.5	
002	RESIDUE-FILTER		411.	
003	FIXED		344.	
004	SULFATE		100.	
005	ALKALINITY-TOTAL		293.	
006	PHENOLPHTALEIN		0.	
007	BICARBONATE		357.1	
008	CARBONATE		0.	
009	CHLORIDE		5.0	
010	CALCIUM		68.3	
011	MAGNESIUM		46.9	
012	HARDNESS-TOTAL		364.	
013	CARBONATE		293.	
014	NON-CARBONATE		71.	
015	ARSENIC	<	0.005	
016	SELENIUM	<	0.0050	
017	LEAD	<	0.005	
018	CADMIUM	<	0.0050	
019	BARIUM	<	0.20	
020	CHROMIUM	<	0.025	
021	SILVER	<	0.01	
022	IRON		0.11	
023	MANGANESE		0.05	
024	ZINC	<	0.10	
025	COPPER		0.05	
026	SODIUM		6.5	
027	POTASSIUM		1.8	
028	MERCURY	<	0.0005	
029	FLUORIDE	<	0.20	
030	NITRATE-N	<	0.05	